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DESCRIPTION OF THE TEMPO II BUDGET ALLOCATION AND HUMAN RESOURCES MODEL

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This paper is one of a continuing series in the area of demographic analysis and economic development prepared by TEMPO, General Electric's Center for Advanced Studies. Other papers in the series include:

Using TEMPO II: A Budget Allocation and Human Resources Model, Stephen Enke et al, April 1973 (GE73TMP-12).

Computer Instructions for TEMPO II, Richard A. Brown, April 1973 (GE73TMP-14).

Offering Bonuses for Reduced Fertility, Stephen Enke, Bryan D. Hickman, January 1973 (GE73TMP-4).

Economic Incentives: A Strategy for Family Planning Programs, Bryan D. Hickman, October 1972 (GE72TMP-33).

Old Age Insurance with Fewer Children, Stephen Enke, Richard A. Brown, March 1972 (72TMP-6).

Declining Birth Rates in Chile: Their Effects on GNP, Education Health, and Housing, Bruce Herrick, Richardo Moran, April 1972 (71TMP-56).

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Calculating the Benefits of Slower Population Growth: A Short Method and Workbook, David N. Holmes, Jr., Richard A. Brown, 1970 (70TMP-87).

Zero Population Growth—When, How, and Why? Stephen Enke, January 1970 (70TMP-35).

Sensitivity Analysis of the Economic-Demographic Model, William E. McFarland, 1969 (69TMP-52).

Raising Per Capita Income through Fewer Births, Stephen Enke, Richard G. Zind, 1969 (69TMP-9).

PREFACE

This document is the technical description of the TEMPO Budget Allocation and Human Resources Model, TEMPO II. It is written for the technical economist who wishes to study the structure, the interactions and feedbacks, and the specific equations of the model.

Two companion documents covering uses and programming of the TEMPO II model are entitled *Using TEMPO II: A Budget Allocation and Human Resources Model,* and *Computer Instructions for TEMPO II.* The former is a brief nontechnical description written for senior policy makers. Its purpose is to acquaint readers with the goals and usefulness of the model. The latter contains computer operating instructions and explains to programmers with limited training how the model's equations and parameters can be modified.

The TEMPO II model is a further extension of TEMPO's work in the integration of economic, demographic and government policy analysis. This particular document was completed under the general supervision of Dr. Stephen Enke. Its technical authors are Dr. William E. McFarland, Dr. James P. Bennett, and Mr. Richard Brown. Other contributors include Professor Donald J. O'Hara of the University of Rochester, Professor Bruce Herrick of the University of California at Los Angeles, Dr. Donald Rugg while at the University of California at Santa Barbara, and Mr. Juan Wicht of the Instituto Nacional de Planificación in Lima, Peru. Continuing encouragement came from Mr. Carl Hemmer of the Office of Population, U.S. Agency for International Development.

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SECTION 1
INTRODUCTION

THE TEMPO ECONOMIC-DEMOGRAPHIC MODELS

TEMPO II, a Budget Allocation and Human Resources Model, represents another step in the evolution of computer simulation models developed to investigate and highlight demographic aspects of economic development and planning. Like the first TEMPO Economic-Demographic Model, it is a highly aggregated model designed to produce heuristic projections applicable to a broad class of less developed countries (LDCs). It also is a flexible model, so that with relatively small modifications it can be adapted for projections applicable to specific LDCs.

The TEMPO models are supply-constrained. That is, output is limited by the availability of resources—eg, capital and labor. This contrasts to common demand-constrained Keynesian macro-economic models, in which an increase in government spending for goods and services leads to higher levels of consumption, investment, and total production. With the TEMPO models, higher government spending on goods and services is accompanied within that same year by an offsetting decrease in consumption and investment, with total production unchanged. The supply-constrained model appears more appropriate for long-term projections of LDCs.*

In addition to being highly aggregated, the first TEMPO model omits explicit treatment of several important elements of a less developed country's development process. In particular, the first model lacks:

1. Feedbacks from social expenditures into the rest of the model
2. An explicit public sector
3. A foreign sector, and
4. Separation of the rural and urban sectors of the economy.†

The present model, TEMPO II, represents the next step in the evolutionary process.§ Improvements over the first model include:

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* While the TEMPO models assume labor may be unemployed, this represents structural unemployment, not unemployment arising from inadequate demand.

† For a complete description of the first model, see William E. McFarland *et al*, *Description of the Economic-Demographic Model*, General Electric—TEMPO, 68TMP-120, Revised Edition, June 1971.

§ Some of the improvements in TEMPO II were anticipated in the specific country applications of the first model. In particular, see Bruce Herrick and Ricardo Moran, *Declining Birth Rates in Chile: Their Effects on Output, Education, Health, and Housing*, General Electric—TEMPO, 71TMP-56, April 1972.

1. An explicit public, or government, sector. The government sector includes a budget, with tax and debt revenues on one side of the budget and government expenditures in eight different areas on the other. Two public sector programs, education and family planning, are considered in some detail.
2. Feedbacks from the government education and family planning programs into the rest of the model. Educational expenditures upgrade the quality of the labor force, and family planning expenditures reduce fertility rates. Government investment also adds to the productive capacity of the economy. On the other hand, government spending programs must compete with private consumption and investment for the limited supply of goods and services available in any given year.
3. Disaggregation of the economy into a subsistence (traditional/rural) sector and a modern sector. In addition, internal migration is now endogenous to the model.

THE MODEL IN BRIEF

The model is composed of three interacting segments: demographic, economic, and government. The population is divided into two sectors, a subsistence sector and a modern sector, each with distinct demographic and economic characteristics. Figure 1 presents a simplified flow chart of the important relationships in the model.

Demographic Relationships

Population growth in each sector is determined by the initial populations, age- and sex-specific fertility, and migration between the two sectors.

The number of births in each sector depends on the female population in the fertile ages and age-specific fertility rates. Fertility rates depend upon the family planning policies of the government, in addition to forces exogenous to the model. Male and female births are assumed to be a constant proportion of total births.

The number of deaths in each sector depends on the size of the population, its age and sex composition, and age- and sex-specific mortality rates. Migration from the subsistence to the modern sector depends on the ratio of per capita wage income of the uneducated modern population to the per capita income of the subsistence population.

Economic Relationships

The gross product of the subsistence sector depends only on the size of the subsistence population, assuming a fixed supply of land and no significant changes in capital or technology. An increase in population is accompanied by a less than proportional increase in output, so that increasing population results in falling per capita output.

The gross product of the modern sector is determined by a modified Cobb-Douglas production function. Output depends on technological change, employed educated

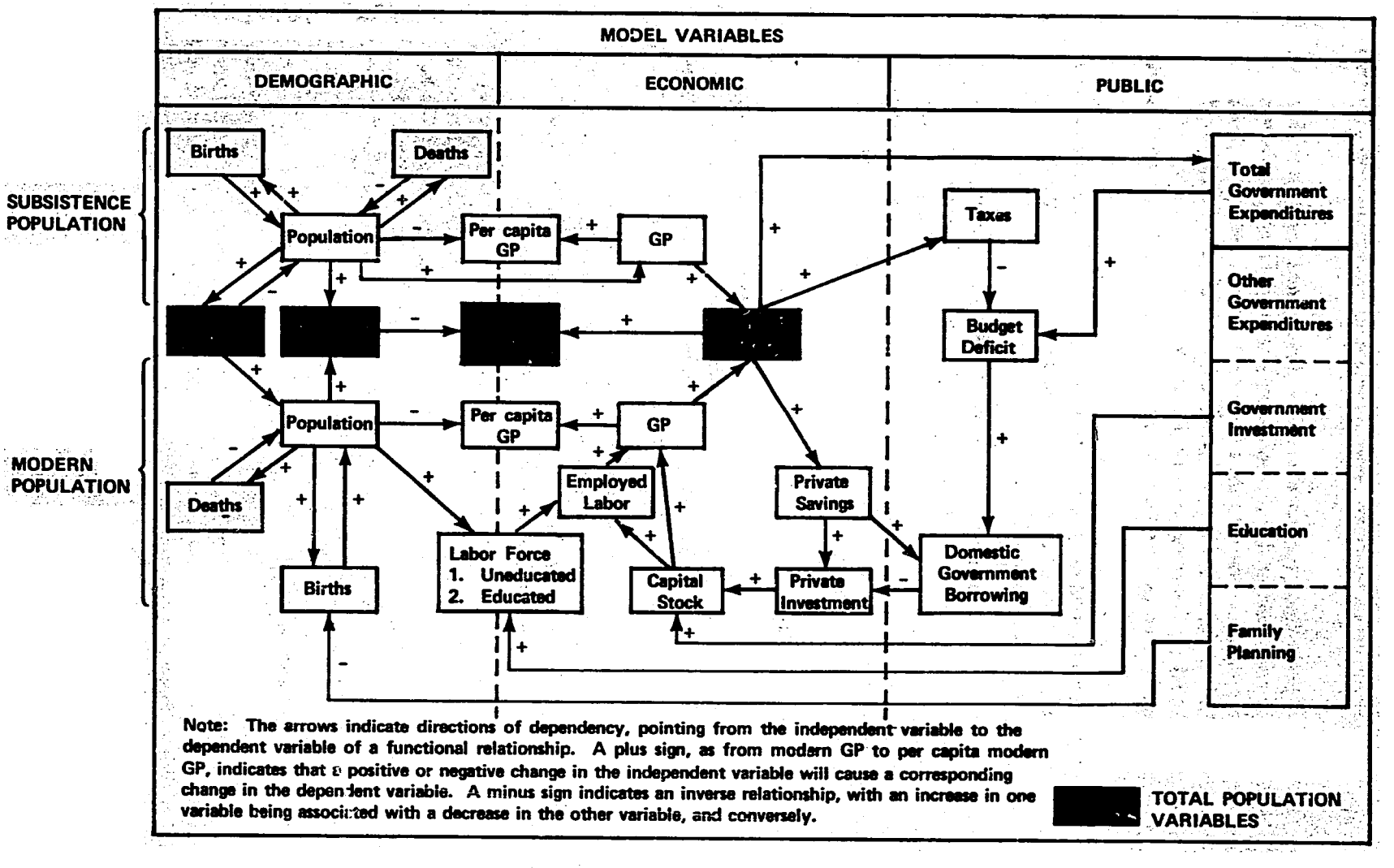

Figure 1. Simplified flow chart of the TEMPO II model.

and uneducated labor, and the capital stock. Technological change is exogenously determined.

The educated and uneducated components of the labor force are determined by the size and age-sex composition of the educated and uneducated populations. These, in turn, depend upon the country's basic demographic rates and the government's education policies. At the option of the user, the uneducated labor force can be adjusted for improved quality due to declining morbidity, with rising per capita income used as a proxy measure of improved nutrition and outlays on health.

The employed uneducated labor force is a function of the total uneducated labor force and the capital-to-labor-force ratio. It is assumed that a constant fraction of the educated labor force is employed.

Change in the capital stock is equal to the sum of private and government investment, less the depreciation of capital stock. Private investment depends on disposable income, consumption, and government borrowing from the private sector. Consumption depends on disposable income and population. Capital accumulation from government investment depends on government policies and the gross product.

Government Program Relationships

The government sector is described in terms of eight different types of outlay—education, family planning, general transfer payments, health, social overhead capital, direct investment, defense, and general government—and three sources of revenue—taxes, borrowing (domestic private and foreign), and new money creation.

Government education and family planning outlays are determined by specified goals (in terms of school enrollment rates and family planning acceptance rates) and the cost of achieving those goals. Each of the other government outlays is specified as a constant or changing fraction of the gross product.

Tax revenue is a function of gross product. Borrowing may come from foreign or private sources. Foreign loans (net of debt service) and grants are determined exogenously. The amount of domestic borrowing depends on the size of the budget deficit and the availability of private savings. The difference between total government outlays and the sum of taxes and borrowing is accounted for by the creation of new money and borrowing from the central bank.

Supply Constraint and Inflation

The sum of private and public purchases of goods and services cannot exceed the total volume of goods and services available. This supply constraint depends upon the economy's productive capacity, as determined by its production functions and resources, supplemented by long-term external aid.

The economy's demands for goods and services (eg, private consumption and investment and government purchase of goods and services) are first calculated independently of the supply constraint. To the extent that demand exceeds supply they must then be reduced. The model's standard assumption is that each component

of demand is reduced by the same proportion. The user, however, has the option of reducing these components by different proportions—for example, private purchases might be forced to absorb the total required reduction.

The initial excess of total demand over the supply constraint is used as a measure of inflationary pressures. The larger the initial excess, the more rapidly prices rise during a given year.

INVESTIGATION OF DEVELOPMENT TRADEOFFS

Development planning constantly involves resource-allocation choices having effects that are not visible for many years, often beyond the time horizon used in formal development plans. The impacts of policies on demographic variables, eg, fertility rates, are often neglected because of the long lags in the subsequent impacts on development. Such effects, however, may be among the most important to the development processes of a country. Here lies the potential value of the TEMPO models to development planning. That is, the model's projections yield insights into the long-term implications of different allocations of development resources.*

For example, many development goals are expressed in terms of the growth of per capita production. If resources are transferred from government investment to family planning, the direct effect will be a reduction in the growth of both production and population. The impact on the growth of per capita gross product depends on the relative size of these two effects, but generally accelerated growth of per capita production would be anticipated.

Other development goals are expressed in terms of increased education of the population, as measured by literacy or enrollment rates. Comparative projections of the TEMPO II model suggest that under many circumstances, a shift of some resources from education to family planning will allow these goals to be achieved at a lower resource cost.

This does not necessarily mean that family planning should be financed even partially by reductions in direct government investment or education expenditures. The user must interpret the comparative projections and implied tradeoffs in terms of his own set of goals and of the opportunity costs of financing direct government investment, education, and family planning from other sources (such as cuts in other government programs, or higher taxes, borrowing, or inflation). Many of these tradeoffs can also be investigated with TEMPO II projections.

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* Although simulation models cannot, by themselves, fill gaps in the understanding of basic relationships, they can be used to more fully investigate the implications of what is known —or thought to be known. They can also help to direct research toward those areas most critical to the longer term planning process.

SECTION 2
TECHNICAL DESCRIPTION OF THE MODEL

This section contains a technical description of the model, with additional comments on the rationale for and interpretation of particular model components. Table 1 lists the important variables in the model and the algebraic symbol for each. Wherever possible, the notation used is consistent with that used in the technical description of the first TEMPO model.*

The model distinguishes two private sectors, modern and subsistence, and a public sector. The modern sector maps imperfectly into the urban/industrial portion of the country and the subsistence sector maps imperfectly into the rural/traditional portion of the country. The public sector is shaped by the government's budget.

The ensuing discussion covers the model's demographic relationships, its economi relationships, the public sector, and additional options available to the user. All subscripts in the model's equations are enclosed in parentheses. To simplify the notation, the time subscript (T) is shown explicitly only if the value of the variable is that of a previous time period. All parameters can be made variable as a function of time by stipulation in the data or minor changes in the computer program.†

DEMOGRAPHIC RELATIONSHIPS

Population Survival

The basic demographic relationships follow standard forms. The size of the population of a given age-sex cohort in either sector (subsistende or modern) is equal to the number of survivors of the age-sex cohort in that sector one year younger in the preceding year, modified by gains or losses due to migration. The population less than 1 year old is computed slightly differently, since it represents the surviving births during the preceding year.

Explicit equations are given here only for the modern male population PMM. Similar equations hold for the modern female population, the subsistence male population, and the subsistence female population.

See William E. McFarland *et al*, *Description of the Economic-Demographic Model*, General Electric–TEMPO, 68TMP-120, Revised Edition, June 1971.

See Richard A. Brown, *Computer Instructions for TEMPO II*, General Electric–TEMPO, GE73TMP-14, April 1973, for more on this.

Table 1. List of variables and symbols.

Demographic Variables	
Description	**Symbol**
Population	
total	P
male	PTM
female	PTF
modern, total	PM
subsistence, total	PS
modern, male	PMM
modern, female	PMF
subsistence, male	none used
subsistence, female	none used
modern, uneducated, total	PMU
modern, uneducated, male	PMMU
modern, uneducated, female	PMFU
modern, educated, total	none used
modern, educated, male	PMME
modern, educated, female	PMFE
Births	
modern, total	BM
subsistence, total	none used
modern, male	BMM
modern, female	BMF
subsistence, male	none used
subsistence, female	none used
Migration (net, subsistence to modern)	
total	MIG
male	MIGM
female	MIGF
Economic Variables	
Gross product	
total	GP
modern	GPM
subsistence	GPS
Labor force (modern only)	
total	none used
educated	LFE
uneducated	LFU
uneducated, adjusted for morbidity	LFUA
Employed labor (modern only)	
educated	NE
uneducated	NU

Table 1. List of variables and symbols (continued).

Economic Variables (continued)	
Description	**Symbol**
Capital stock	K
Consumption, private	C
Savings, private	S
Investment, private	PINV
Disposable income	DI
Price index	PI
Total demand for goods and services	DGS
Total available goods and services	AGS
Government Program Variables	
Government outlays	
total	G
education	ED
family planning	FP
general transfers	TR
health	HL
social overhead capital	SOC
direct government investment	DGI
defense	DO
general	GG
Tax revenue	TAX
Borrowing	
domestic	BOR
foreign	GFB
Government deficit	DEF
Education outlays	
total	ED
primary	PRICOST
secondary	SECCOS
tertiary	TERCOS
professional	PROCOS
Number of family planning acceptors	ACC
Cost per family planning acceptor	ACOST
Family planning incentive payments	none use
Total transfer payments	TRFP
Government purchases of goods and services	GGS

Infants. PMM(0), the modern male population less than 1 year old at time T, is the infant male survival rate s(MMI) times the number of births BMM in the previous time period modified by the migration correction MIGM(0).

$$PMM(0) = s(MMI) \cdot [BMM(T-1) + MIGM(0,T-1)] \tag{1}$$

Ages 1 Through 64. PMM(i), the population age i at time T, is the appropriate survival rate s(MM) times the population of age i-1 in the previous time period modified by migration MIGM(i-1).

$$PMM(i) = s(MM,i-1) \cdot [PMM(i-1, T-1) + MIGM(i-1, T-1)],$$

$$i = 1, \ldots, 64 \ . \tag{2}$$

Age 65 and Older. The population aged 65 and above at time T consists of the survivors of those 65 and above at T-1 plus the survivors of those aged 64 at time T-1, each corrected for migration.

$$PMM(65+) = s(MM,65+) \cdot [PMM(65+, T-1) + MIGM(65+, T-1)]$$

$$+ s(MM,64) \cdot [PMM(64, T-1) + MIGM(64, T-1)] \ . \tag{3}$$

Births

The number of births of both sexes during period T is the summation over the fertile ages of the product of each age-specific fertility rate b(i) and the female population of appropriate age. Male births BMM are some fraction r of total births BM, and the remainder are female births BMF. Algebraically,

$$BM = \sum_{15}^{49} b(i) \cdot PMF(i, T-1) \tag{4}$$

$$BMM = r \cdot BM \ , \tag{5}$$

and

$$BMF = (1-r) \cdot BM \ . \tag{6}$$

The age-specific fertility rates may change through time, either exogenously or due to the impact of government family programs. (See "Family Planning Budget," page 18.)

Note that if fertility rates in the modern sector are below those in the subsistence sector, migration to the modern sector reduces the fertility of the migrants and hence the average fertility of the population as a whole. The present formulation

of the model exaggerates the impact somewhat by assuming that the reduction of fertility occurs immediately.

Migration

Migration from the subsistence sector to the modern sector is assumed to depend on the ratio of per capita wage income of the uneducated modern population to per capita income of the subsistence population. Specifically, total net migration MIG is

$$MIG = m(1) \cdot R^{m(2)} \cdot PS \ ,$$

where

$$R = \frac{w \cdot GPM(T-1)}{PMU(T-1)} \div \frac{GPS(T-1)}{PS(T-1)} \tag{7}$$

The uneducated modern population PMU is assumed to receive as wage income a share of the modern gross product GPM equal to w, the output elasticity of uneducated labor in the modern sector production function (from Equation 15).* The parameter m(2) measures the sensitivity of the subsistence population to changes in the ratio of incomes. It implicitly takes into consideration such factors as the cost of migration, differences in the cost of living, cultural differences, and imperfect information and perceptions. By setting m(2) equal to zero, net migration becomes a constant proportion of the subsistence population—ie, migration becomes totally insensitive to the income ratio. The other parameter, m(1), is adjusted so as to obtain the appropriate initial rate of migration.

The age-sex composition of the migrants is determined by a set of exogenously specified weights,

$$MIGM(i) = \left(\frac{MIG}{MW}\right) \cdot m(M,i) \cdot PSM(i)$$

and (8)

$$MIGF(i) = \left(\frac{MIG}{MW}\right) \cdot m(F,i) \cdot PSF(i)$$

where MIGM(i) and MIGF(i) are the respective male and female migrants of age i, m(M,i) and m(F,i) are sex- and age-specific weights, and

$$MW = \sum_i [m(M,i) \cdot PSM(i) + m(F,i) \cdot PSF(i)]$$

---

* The income available in the modern sector is perceived by the potential migrant to come only from wages. The uneducated modern population may receive some nonwage income, but such income is assumed to play no explicit role in the migration decisions.

If all of the weights (ie, the m's) are equal, an equal *percentage* of each age and sex cohort of the subsistence population will migrate during any given year. For example, if total migration represented 2 percent of the total subsistence population, then 2 percent of each age and sex cohort would migrate.

If, however, all female age-cohorts were given weights one-half those given to the male cohorts, then the percentage of the subsistence male population that migrated would be twice the percentage of the female subsistence population that migrated. The adjustment by the fraction MIG/MW establishes the specific migration rate of each cohort that is required to achieve the correct total migration.

ECONOMIC RELATIONSHIPS

The Supply Constraint and Prices

Economic and government budget variables may be expressed in any of three different types of measure: (1) constant base year prices, or "real" values, (2) current prices, or (3) preliminary values. The user may either interpret the preliminary values of variables as pure computational constructs or attach some behavioral meaning to them. For example, preliminary values of economic variables might be regarded as computational constructs needed to obtain their constant and current price values, and the preliminary values of government budget variables might be regarded as "target" values.

Capital is referred to here only in constant price terms. Superscripts are used to distinguish the three types of measure for the other variables, "a" for constant prices, "m" for current prices, and "p" for preliminary.

The total preliminary demand for goods and services DGS is the sum of three components: the preliminary values of private consumption C, private investment PINV, and government purchases of goods and services GGS.

$$DGS^p = C^p + PINV^p + GGS^p \qquad (9)$$

The preliminary values for each of these variables are determined as described in the equations given below.

The total volume of available goods and services, AGS, is the sum of gross production GP and long-term external aid GFB, all measured in base year prices,*

$$AGS^a = GP^a + GFB^a \qquad (10)$$

No distinction is made in the model between gross national product and gross domestic product.

To remain within the supply constraint imposed by available goods, total demand must be reduced to some fraction, adj, of its preliminary value. Thus, the final demand for goods and services is

* No provision is made for depletion of inventories since inventory fluctuations can be safely ignored in long-term projections.

$$DGS^a = adj \cdot DGS^p = AGS^a \quad , \tag{11}$$

where

$$adj = \frac{AGS^a}{DGS^p}$$

It is assumed here that each component of planned purchases is reduced proportionally. That is,

$$C^a = adj \cdot C^p$$

$$PINV^a = adj \cdot PINV^p \tag{12}$$

and $GGS^a = adj \cdot GGS^p$

The user, however, can easily modify the model so that the burden of the supply constraint falls more heavily on some components of demand than others. For example, one might assume that target government purchases are always realized, and the required reductions affect only private purchases. Algebraically,

$$GGS^a = GGS^p \text{ , } C^a = adj \cdot C^p \text{ , and } PINV^a = adj \cdot PINV^p$$

where

$$adj = \frac{AGS - GGS^a}{DGS - GGS^p}$$

The ratio of the preliminary demand for goods and services to the total available, DGS^p/AGS^a, is a measure of inflationary pressures in the economy. In particular, it is assumed that

$$\frac{\Delta PI}{PI(T-1)} = \left(\frac{DGS^p}{AGS^a}\right)^{infl} - 1 \tag{13}$$

where the percent change in the general price index PI is 100 times $\Delta PI/PI$, and infl is a parameter measuring the sensitivity of the price index to inflationary pressures. By this formulation, an initial excess of demand over available supply of 4 percent would result in a price rise of 4 percent if infl had a value of one and 8 percent if infl had a value of two.

Production

Subsistence Sector. Gross product in the subsistence sector, GPS, depends only on the size of the subsistence population PS. Production is made dependent on total population because of the ambiguity of the conventional labor force/non-labor force dichotomy in traditional rural populations. Algebraically,

$$GPS^a = x \cdot PS(T-1)^y \qquad (14)$$

An increase in population of 1 percent results in an increase in output of y percent. Since the subsistence population is working with little capital and a fixed quantity of land, y is normally less than one. That is, an increase in population does not increase output proportionately and per capita production falls.

Modern Sector. Gross product in the modern sector, GPM, is given by a Cobb Douglas type production function that includes technological progress, capital stock, and two types of labor; ie,

$$GPM^a = z \cdot (1 + q)^T \cdot K(T-1)^u \cdot NE(T-1)^v \cdot NU(T-1)^w \ . \qquad (15)$$

The parameter q measures technological progress, or the extent to which improvements in technique and organization permit more output to be obtained from given inputs. K is the stock of capital measured in base year prices, NE is employed educated labor, and NU is employed uneducated labor. The exponents u, v, and w are output elasticities; a 1 percent increase in capital, educated labor, or uneducated labor increases output by u, v, or w percent, respectively.*

Gross product is the sum of the gross products of the two sectors;

$$GP^a = GPM^a + GPS^a \qquad (16$$

Total Labor Force in the Modern Sector

For purposes of obtaining labor force projections, the modern sector population is separated into two groups by level of education.† These groups have different economic characteristics and make different contributions to modern sector output. The user supplies a breakdown of the initial labor force by education and the education level of subsequent labor force entrants is determined by government education policy.

The number of people in the educated and uneducated portions of the modern sector labor force (LFE and LFU, respectively) is obtained by applying age- and sex-specific labor force participation rates to the appropriate populations. That is,

$$LFE = \sum_{15}^{64} [p(ME,i) \cdot PMME(i) + p(FE,i) \cdot PMFE(i)]$$

For an additional discussion of the Cobb-Douglas and other common forms of the production function, see R.G.D. Allen, *Macro-Economic Theory,* New York, St. Martin's Press, 1967, Chapter 3.

No attempt is made in this model to ascribe different demographic characteristics to the groups separated by education, in spite of the common observation that those with more education and income tend to have lower mortality and fertility rates.

and

$$LFU = \sum_{5}^{64} [p(MU,i) \cdot PMMU(i) + p(FU,i) \cdot PMFU(i)] \qquad (17)$$

where PMME, PMFE, PMMU, and PMFU are the educated male and female and uneducated male and female populations, respectively, by age cohorts, and the p's are the appropriate participation rates.

At the option of the user, the quality of the uneducated labor force can be adjusted for increasing productivity due to declining morbidity. Algebraically,

$$LFUA = LFU \cdot \left[\frac{GPM^{a}(T-1)/PM(T-1)}{(GPM/PM)(0)}\right]^{h} \qquad (18)$$

where (GPM/PM)(0) is the initial per capita product in the modern sector. The index of real per capita product in the modern sector (ie, the expression in brackets) is taken as a proxy for improvement resulting from such things as increased household expenditures on health, increased public health budgets, and improved nutrition. If the user wishes to eliminate the impact of these factors, or to place them under general technological progress, the parameter h can be set to zero and the effective labor force is equated with the enumerated labor force.

Employed Labor Force in the Modern Sector

Employed educated labor NE is assumed to be a constant fraction ne of the educated labor force;

$$NE = ne \cdot LFE \ . \qquad (19)$$

Employed uneducated labor NU at time T is some fraction of the adjusted uneducated labor force LFUA. This fraction increases as the capital-labor ratio increases, approaching asymptotically some maximum rate of employment, k(1).

$$NU = k(1) - k(2) \cdot \left[\frac{LFU(T-1)}{K(T-1)}\right] \cdot LFUA \qquad (20)$$

The second parameter, k(2), is chosen so as to obtain the appropriate initial rate of employment.

The employment function is based on the assumption that unemployment results primarily from a growth of the labor force too rapid to be utilized (or "absorbed" by the available stock of capital, ie, all unemployment is structural. A more rapid growth of capital relative to the growth of labor therefore results in a higher rate of employment.*

* A more complete discussion of a variant of this employment function is given in *Description of the Economic-Demographic Model*, 68TMP-120 (Revised), and is reproduced as an Appendix in this document in a slightly edited form.

Disposable Income and Consumption

Preliminary consumption C is a function of disposable income DI and population. Preliminary disposable income is gross product less taxes TAX plus total transfer payments TRFP. (Total transfer payments are the sum of general transfers, such as direct welfare payments, and family planning incentive payments.) Because corporations are not separated from households in the accounting framework of the model, disposable income includes disposable household income and the gross earnings (including depreciation but net of taxes) of private businesses. Algebraically,

$$DI^p = GP^a - TAX^p + TRFP^p$$

$$C^p = c(1) \cdot DI^p + \delta \cdot P \qquad (21)$$

where

$$\delta = c(2) \cdot \left[\frac{DI/P}{(DI/P)(0)}\right]^{c(3)} \quad , 0 \leq c(3) \leq 1$$

and (DI/P)(0) is the initial value of per capita disposable income.

The parameter c(1) is the lower bound of the average propensity to consume (ie, C/DI). The index number for per capita income modifies the effect of population growth by introducing an upward shift of the consumption rate as per capita income increases. Note that if c(3) has a value of zero, total consumption becomes a linear function of disposable income and population. If c(3) has a value of unity, population is eliminated from the consumption function and consumption becomes proportional to disposable income.

As noted above, "real" consumption will generally be some fraction of preliminary consumption, or $C^a = adj \cdot C^p$.

Private Savings, Investment, and the Capital Stock

Preliminary private savings S is equal to preliminary disposable income minus preliminary consumption. Preliminary investment by the private sector PINV is total savings minus the preliminary amount of government borrowing BOR:

$$S^p = DI^p - C^p \qquad (22)$$

and $PINV^p = S^p - BOR^p$

Again, "real" private investment is some fraction of preliminary private investment; $PINV^a = adj \cdot PINV^p$.

The capital stock K at time T is the previous period's capital stock less depreciation, ie, $(1.0 - d) \cdot K(T-1)$, plus real private investment PINV and increments

resulting from direct government investment DGI and government investment in social overhead capital SOC.

$$K = (1.0 - d) \cdot K(T-1) + f(1) \cdot DGI^a + f(2) \cdot SOC^a + PINV^a \qquad (23)$$

Capital stock is measured in constant base year prices. The coefficients f(1) and f(2) are applied to DGI and SOC to adjust for expenditures in these areas that do not add to the productive capacity of the economy. (See pages 17 and 19 for discussions of government investment and borrowing.)

Current Price Value of Economic Variables

The current price value of each of the economic variables is the product of the price index (determined in Equation 13) and either (1) the constant price or real value of the variable (with an "a" superscript) or (2) the product of the preliminary value of the variable (with a "p" superscript) and the adjustment factor, adj. For example, $GP^m = PI \cdot GP^a$ and $DI^m = PI \cdot adj \cdot DI^p$.

PUBLIC SECTOR

Government Outlays

Total government outlays G are the sum of eight budget components: education ED, family planning FG, general transfers TR, health HL, social overhead capital SOC, direct government investment DGI, defense DO, and general government GG.

$$G^p = ED^p + FP^p + TR^p + HL^p + SOC^p + DGI^p + DO^p + GG^p . \qquad (24)$$

Government purchases of goods and services GGS include all government outlays except for transfer payments, which consist of both general transfers and any financial incentive payment funds that may be in the family planning budget.

Each of the major budget components, except for education and family planning, is targeted in terms of a specified percent of gross product, eg,

$$\begin{aligned} GG^p &= g(1) \cdot GP^a \\ DGI^p &= g(2) \cdot GP^a \\ SOC^p &= g(3) \cdot GP^a \\ &\text{etc.} \end{aligned} \qquad (25)$$

The particular percentages, g(1), g(2), etc, which can be changed through time, are policy instruments chosen by the user of the model.

Outlays on education ED and family planning FP are also policy instruments, but are specified in terms of policy *goals*—as contrasted with policy *budgets*. Th

education goals are specified in terms of projected enrollment rates, and the family planning goals in terms of acceptance rates. The education and family planning budgets are determined by the cost of achieving the specified goals, given the sizes of the appropriate subpopulations to which the rates apply. The education and family planning goals are assumed to be always realized. This requires that the target budgets for these two programs be adjusted upward just enough to offset the downward adjustment necessitated by the supply constraint. Thus,

$$ED^p = \frac{1}{adj} \cdot ED^a$$

$$\text{and} \quad FP^p = \frac{1}{adj} \cdot FP^a \tag{26}$$

where ED^a and FP^a are the constant price costs required to achieve the programs' objectives.* These two components of the budget are discussed in more detail subsequently.

Actual government purchases are related to target purchases in the same manner described above for consumption and private investment, ie,

$$GGS^a = adj \cdot GGS^p .$$

A similar treatment applies to the components of GGS.

Two types of government expenditure, direct government investment and social overhead capital, add directly to the economy's stock of capital. (See "Private Savings, Investment, and the Capital Stock," page 15.) Direct government investment includes expenditures for such things as publicly owned manufacturing facilities. Since some of these expenditures may not add directly to the economy's productive capacity, only a portion of direct government investment is added to the stock of capital. A portion of the government's investment in social overhead capital, such as expenditures for dams and transportation systems, also adds directly to the economy's stock of productive capital.

Education Budget. The educational goals of the government are specified in terms of projected age- and sex-specific enrollment rates for each type of school, ie, primary, secondary, tertiary, and professional. The cost of achieving the enrollment goal for each type of schooling is then the product of the constant price cost per student, the enrollment rate, and the size of the appropriate population cohort. Algebraically, for primary education

$$PRICOST = \beta \cdot \left[\sum_i a(M,i) \cdot PTM(i) + \sum_i a(F,i) \cdot PTF(i) \right] \tag{27}$$

This treatment allows the user to investigate the implications of *achieving* prespecified education and family planning goals. There is also an alternative option of specifying budget ceilings for the education and family planning budgets in the same manner as described in Equation 25 for the other six expenditure programs, ie, as percentages of gross product. This option is discussed under "Additional Options," page 20.

where PRICOST is the required educational budget for primary schooling, β is the per-student cost of primary schooling measured in base year prices, a(M,i) and a(F,i) are the respective male and female enrollment rates for age i, and PTM(i) and PTF(i) are the respective male and female populations of age i.

The costs of achieving the enrollment goals for the other three types of schoolin are determined in the same fashion. The total education budget is the sum of the costs for the four types of schooling, ie,

$$ED^a = PRICOST + SECCOST + TERCOST + PROCOST \quad , \tag{28}$$

where the last three terms represent the respective costs of secondary, tertiary, and professional schooling measured in base year prices.

Family Planning Budget. The family planning goals are specified in terms of projected family planning acceptance rates, ie, in time T a specified portion of the modern female population is assumed to have accepted contraception. It is also assumed that fertility rates decline proportionally with the percentage of females of fertile age who accept contraception. The family planning budget is the cost of achieving these goals.

The computation of cost requires the determination of the number of family planning acceptors and the cost per acceptor. The number of acceptors ACC is the product of the projected acceptance rate and the total modern female population of fertile age, ie,

$$ACC = rate \cdot \sum_{5}^{49} PMF(i) \tag{29}$$

The cost per acceptor (measured in base year prices) depends upon the rate of acceptance. It is assumed that up to a specified rate of acceptance, srate, the only cost for an acceptor is a standard and constant cost of supplying the necessary contraceptive supplies.

To obtain and service acceptors beyond the specified rate, however, additional costs are incurred. In the model, the additional costs are assumed to increase as the acceptance rate increases. Thus, the cost per acceptor, ACOST, is

$$ACOST = \begin{cases} \pi(1), \text{ if rate} < \text{srate} \\ \quad \text{or} \\ \pi(1) + \pi(2)\ [\text{rate} - \text{srate}], \text{ if rate} \geq \text{srate} \end{cases} \tag{30}$$

.*

A portion of the family planning costs may take the form of incentive payments to acceptors and subsidies to suppliers, which represent transfer payments. That is, they are income to the recipients for which no productive services are rendered in return. For a more comprehensive discussion of the use of transfer payments and other incentives (continued on next page

The total family planning budget is then the product of the cost per acceptor and the number of acceptors,

$$FP^a = ACOST \cdot ACC \quad , \tag{31}$$

where FP^a and ACC are measured in base year prices.*

Government Sources of Funds

The government finances its outlays from tax revenue TAX, government borrowing from the private sector BOR, and the creation of new money. At the option of the user, the government may also receive funds from foreign loans and grants, GFB, specified as a percentage of gross product (see "Additional Options," page 20

Target tax revenues TAX are proportional to gross product,

$$TAX^p = t \cdot GP \quad ,$$

where t is the average tax rate. This proportion can be specified to change linearly through time.

The difference between total government outlays G and taxes is the deficit DEF to be financed,

$$DEF^p = G^p - TAX^p \quad . \tag{32}$$

This deficit is financed through a combination of domestic borrowing from the private sector BOR and the creation of new money or borrowing from the central bank. It is assumed that the government finances the deficit as much as possible through domestic borrowing, but that this borrowing cannot exceed some fixed portion of private savings S. Algebraically,

$$BOR^p = \text{Minimum of } (DEF^p \text{ or } a \cdot S^p) \tag{33}$$

where "a" is the maximum portion of private savings that can be borrowed by the government. The remainder of the deficit is assumed financed by the creation of new money or borrowing from the central bank.

(continued from preceding page) in family planning programs, see Bryan D. Hickman, *Economic Incentives: A Strategy for Family Planning Programs*, General Electric—TEMPO, GE72TMP-33, October 1972 and Stephen Enke and Bryan D. Hickman, *Offering Bonuses for Reduced Fertility*, General Electric—TEMPO, GE73TMP-4, January 1973.

As a side calculation, the number of births averted, AVERT, is determined by the following equation:

$$AVERT = [rate/(1.0 - rate] \cdot BM$$

where BM is the actual number of modern sector births.

Current Price Value of Budget Variables

The current price value of each of the budget variables is the product of the price index and either (1) the constant price value of the variable or (2) the product of the target value of the variable and the adjustment factor. For example, $ED^m = PI \cdot ED^a$, and $TR^m = PI \cdot adj \cdot TR^p$.

ADDITIONAL OPTIONS

Foreign Sector

As presented above, there is no foreign sector. The user, however, can specify an inflow of foreign loans and grants to the government GFB as a percent of gross product, ie,

$$GFB^a = gfb \cdot GP^a \tag{34}$$

where both variables are measured in base year prices. The foreign loans and grants (net of debt service) are added to the government's tax revenue, with appropriate adjustments being made when dealing with either the target budget or budget in current prices. This external aid, measured in base year prices, also augments the available supply of goods and services AGS. The domestically financed deficit is then the difference between total government outlays and the sum of tax revenues and foreign loans and grants. Domestic borrowing and money creation are then determined in the same manner as presented above.

Except for foreign loans and grants to the government, the present model has no foreign transactions. The foreign sector will receive substantial attention during subsequent evolution of the model.

Government Budget Impact of Education and Family Planning Expenditures

As discussed above, education and family planning expenditures are net additions to total government outlays. The user, however, can consider the total government budget to be constrained, eg, to 15 percent of the gross product. With the imposition of such a constraint, growth of the education and family planning budgets requires a reduction in other budget categories. Each of the other budget components may receive the same proportional cuts, or the user may allocate the budget cuts by some set of specified weights.

Budget ceilings can also be imposed upon the education and family planning budgets in the same manner as described above for the other six expenditure programs, ie, as percentages of gross product. If the attainment of the enrollment or acceptance rate goals requires an expenditure in excess of that allowed by the budget ceiling, the goals are reduced by the amount necessary to remain within the ceiling.

SECTION 3
USES AND INTERPRETATION OF THE MODEL

TWO USES OF THE MODEL

TEMPO II is intended for use in two different types of situations. The first is as an instrument for generating general and heuristic projections applicable to a large class of LDCs, but not claiming to describe the circumstances of any particular country.* The second use is country-specific applications. For these applications the user will generally want to tailor the model's functional form as well as the numerical value of parameters to the circumstances of the specific country. The model has been constructed to expedite at least some of the more important functional changes.

In either type of use—general-heuristic or country-specific—the primary purpose of the model is to investigate the long-term(eg, 30-year) effects of different assumptions about demographic rates and government policies affecting those rates, in addition to gaining insights into other types of development planning tradeoffs. The basic procedure is to make comparative projections in which all data are identical except those describing particular assumptions being contrasted.

PROJECTIONS VERSUS FORECASTS

Especially in the general applications, the user is cautioned against using the projections computed with the model as though they were "forecasts," at least as the term is commonly used. A projection illustrates what would happen *if* its underlying assumptions were satisfied over the projection period. A forecast *predicts* that certain events will occur or that a certain probability exists that they will occur. Forecast models are generally econometrically estimated, and the forecasts extended no more than a few years into the future.

The projections, *used in combination,* demonstrate the relative effects of different assumptions on the growth of various variables of interest. These comparisons, in terms of the *relative* growth rates or *relative* values of variables, are much more robust (ie, less sensitive with respect to changes in the numerical or functional specification of the model) than the growth rates and values of a variable in any *single* projection.

For example, over a wide range of conditions an increase in the rate of technological progress (parameter "q" in Equation 15, Section 2) by 1 percentage point

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* The general attributes include high fertility rates, death rates in the mid-to-late downward transition, and low per capita incomes.

results in a 1.5 percentage point increase in the growth rate of gross product over a 30-year projection. For a single projection, this is a substantial increase. However, the growth of gross product remains relatively insensitive to changing fertility conditions, so that the ratio of the gross products 30 years into the future from two projections differing only in fertility assumptions is virtually unchanged by the assumed increase in technological progress.*

The above remarks apply to all uses of the projections. However, in the case of country-specific applications, a user will often want to attach more significance to a single projection. Accompanied by a properly cautious attitude, this interpretation *may* be valid. The user will attempt to use parameter values that describe most nearly the conditions in his country, even though perhaps doubling or halving a parameter value might leave the comparative projection results unchanged. If he feels sufficiently confident about the fit of the model to his country, he may attach the properties of a conditional forecast to some of the qualitative results of the projection. Even under the best conditions, however, one should be extremely cautious about attaching much significance to the value of a variable from a single projection 30 years into the future.

INVESTIGATION OF TRADEOFFS

One of the most important uses of the model—either general or country-specific—is in the investigation of development planning tradeoffs. During any given year, the goods and services available to the economy are relatively fixed. Within limits, however, the uses of these resources are subject to discretionary changes. Thus, the government may decide to spend more or less in its various programs, eg, direct investment, education, or family planning. If it decides to increase the spending in a particular program, this must come at the expense of other programs or at the expense of private spending for consumption and investment. These decisions made over a period of years may have significant impact on the total development of the country, and consequently on the long-run availability of goods and services. These tradeoffs and their consequences can be investigated with the use of the model.

For example, the user might want to investigate the impact of a family planning program on the government budget, leaving all other budget specifications unchanged. He can generate two projections that have identical assumptions, except that one includes a family planning program in the government budget and the other does not. The impact depends primarily on what happens to the education budget. If it is assumed that the education budget is goal-specified, as described in Section 2, the two projections have identical education budgets during the early years. However, as the family planning program lowers fertility rates, there is slower growth in the number of school-age children—and consequently a slower growth in the education budget—in the projection with family planning. As the projection extends further into the future, this differential increases as the family planning program reaches more families and as older age-cohorts are affected by the fertility changes.

See William E. McFarland, *Sensitivity Analysis of the Economic-Demographic Model*, General Electric—TEMPO, 69TMP-52, July 1969 for a discussion of these matters as applied to the first TEMPO model.

The family planning budget will generally increase throughout the 30-year projection. Thus, during the early years of the projection, the addition of the family planning program causes a net addition to government spending. Later, however, the reductions in education spending required to achieve the specified goal begin to offset the cost of the family planning budget. Eventually, the projection with family planning may actually have smaller total government spending than the projection without family planning.

This outcome is not so robust, however, as the projection of gross product discussed in the preceding example. The impact on the projected government budget is sensitive to several conditions that may differ substantially from one country to another. This leads to a very important element in the use and interpretation of the model—sensitivity analysis.

SENSITIVITY ANALYSIS

The extent to which the slower growth of the education budget (resulting from the slower growth of school-age population) offsets the growing family planning budget depends heavily on the assumptions used, for example, the unit costs assumed in both the family planning and education budgets. The lower the family planning unit costs and the higher the education unit costs, the greater will be the offset relative to the growing family planning budget. The composition of the education budget with respect to primary, secondary, the higher levels of education can also influence the outcome. The larger the share of the budget in the lower grades, the larger will be the impact on the education budget and the sooner it will be felt.

Initial experiments suggest that under one set of plausible assumptions the addition of the family planning program might result in a decrease in total government spending beginning midway through the projection. Under a different set of plausible assumptions, total government spending may be higher by 5 to 10 percent during the last half of the projection.

It follows that one needs to be more careful when generalizing the results discussed above with respect to the impact of a family planning program on total government spending than when generalizing about the insensitivity of gross product to different fertility assumptions. Also, this highlights an area in which the user has a narrower margin for error in country-specific applications.

A continuing sensitivity analysis of the TEMPO II model is in progress, testing the sensitivity of various results to a wide range of parameter values. The results from some of these tests will be available on request at a later date. Any user, however, should consider the sensitivity analysis—both by TEMPO and by himself—as an integral part of the use of the model.

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APPENDIX
EMPLOYMENT FUNCTION OF THE EARLIER TEMPO MODEL

The employment function used in the earlier TEMPO model takes the form:

$$N_t = \left(1 + g\,\frac{K_t - K_{t-1}}{K_{t-1}}\right) N_{t-1}$$

and

$$g = h\left[\frac{(L_{t-1} - N_{t-1})/L_{t-1}}{(L_0 - N_0)/L_0}\right]$$

where N is employed labor, K is the stock of capital, and L is the labor force.* The subscript 0 indicates that these are initial values.

This employment function is based on the assumption that unemployment results primarily from a growth of capital that is too slow to utilize (or "absorb") the available supply of labor. A more rapid growth of capital will result in a more rapid growth of employment.

It also assumes that for a given state of technology and real cost of capital—both determined exogenously in the model†—the incremental capital-labor ratio depends on the real cost of labor. The real cost of labor depends on the state of the labor market, for which the unemployment rate $(L - N)/L$, is the best single measure. (L is the available labor force, and N is the amount of employed labor.) As the unemployment rate falls, the labor market tightens and upward pressures are placed on the real cost of labor.§

Thus, as the unemployment rate falls, the incremental capital-labor ratio tends to increase and the growth in employed labor which results from a given growth in

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* In the earlier TEMPO model no distinction is made between educated and uneducated labor.

† Although the state of technology appears explicitly as part of the production function, the cost of capital operates only implicitly through the employment function.

§ A tightening of the labor market places upward pressures on real wages. It also creates shortages of particular types of labor skills, causing substitution of inferior types of labor. Although the model does not treat wage rates explicitly and has only one variable for the labor force, L, implying some sort of homogeneity, both wage rates and the heterogeneous nature of labor operate implicitly in the employment function.

the capital stock becomes smaller. (The reverse takes place when the unemployment rate rises.) In the extreme case of full employment, ie, a zero unemployment rate, employment cannot increase regardless of how rapidly capital grows. In practice, it is usually difficult to drive the unemployment rate below some level for any feasible growth rate of capital.

The coefficient h has two roles. The first is to determine the initial relationship between the growth rates of the capital stock and employed labor. Initially, $g = h$. If h is larger than unity, employed labor initially grows more rapidly than the capital stock. If h is less than unity, employed labor initially grows less rapidly than the capital stock. If h has an initial value of unity, the unemployment rate will rise, fall, or remain constant, depending on whether the growth rate of capital is less than, greater than, or equal to the growth rate of the labor force.

The second role is to determine the effect of a given change in the unemployment rate on the coefficient g. The larger h is, the larger will be the change in the proportionality coefficient, g, which results from a given change in the rate of unemployment. Thus, it measures the sensitivity of the incremental capital-labor ratio to changes in the unemployment rate. In other words, the effects of an increase in h are (1) to increase the value of g for any given unemployment rate, and (2) to increase the sensitivity of g to changes in the unemployment rate.

For example, assume that the value of h is unity and let the initial conditions give a labor force of 1.0 million growing at 3 percent per year, with initial unemployment of 100,000. The percent growth of employed labor will be equal to the percent growth of capital. If capital grows 3 percent the first year, employed labor will grow at the same speed as the labor force and the unemployment rate will remain at the initial value of 10 percent (103,000 employed out of a labor force of 1.03 million).

Assume that at some time in the future, say 1995, the labor force has increased to 2.0 million and is still growing 3 percent per year. Assume also that the growth rate of capital is 6 percent and that the unemployment rate has fallen to 7.5 percent, ie, 150,000 are unemployed. There are 1.85 million employed. In 1996, the labor force will be 2.06 million. The value of g will have dropped to 0.75*, meaning that the growth of employed labor will be 4.5 percent, three-fourths of the percentage growth of capital. In 1996, 1.933 million will be employed labor. The number of unemployed will fall to 127,000 (2.06 million less 1.933 million) and the unemployment rate will fall to 6.2 percent.

The value of g falls as the ratio of the current to the initial unemployment rate gets smaller. Let h have a value of unity. If the unemployment rate falls to 3.5 percent from an initial value of 14.0 percent, the value of g will fall from 1.00 to 0.25. This means that employment will grow at only one-fourth the

$$g = \frac{(L_{t-1} - N_{t-1})/L_{t-}}{(L_0 - N_0)/L_0} = \frac{0.075}{0.100} = 0.75$$

speed of the stock of capital. If the labor force is growing 3 percent per year, capital must grow at an annual rate in excess of 12 percent to lower the rate of the unemployment any further. This is a healthy rate of growth for any country.

Should the unemployment rate drop to 2 percent, capital would have to grow in excess of 21 percent per year to obtain further reductions in the unemployment rate. It is evident that reductions in the rate of unemployment become successively more difficult—eventually virtually impossible—as the unemployment rate approaches zero.

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16. Abstract

This document is a technical description of the TEMPO II Budget Allocation and Human Resources Model, an economic-demographic simulation model. It describes the model's equations and discusses some alternative formulations. The final section of the document discusses certain technical aspects of the uses of the model, such as the role of sensitivity analysis.

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