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PLANNING IN SMALL, OPEN ECONOMIES:

A MODEL FOR RELATING CAPITAL INFLOWS,

DEBT SERVICE AND PROFIT TRANSFERS

by

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INTRODUCTION 1/

The relationship between capital imports and future transfer payments associated with them constitutes one of the most serious planning problems confronted by many less-developed countries. We argue that this problem is especially critical for small, open economies, as defined below. In the absence of systematic methods to evaluate alternative patterns of capital inflow in terms of their future balance of payments claims, decisions have tended to be made on an ad hoc basis. This has resulted in recurring balance of payments crises in many less-developed countries and irregular, unplanned inflow of foreign capital. The contribution of foreign capital to economic development could be greatly enhanced by rational and conscious planning of the maximum inflow consistent with future debt service capacity. The purpose of this first paper on planning in small, open economies is to develop an aggregate model to enable planners to incorporate this basic relationship in the context of a consistent, logical framework. Later papers will be concerned with statistical application of the model to this problem, as well as to other aspects of planning in the small, open economy context, for example by expanding this model to include the government sector.

This paper, therefore, is concerned with a class of planning models appropriate to studying the interrelations among growth, foreign capital, and debt service. A series of successively more realistic models is

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1/ I wish to express my appreciation to Douglas Paauw for his constant encouragement and assistance in this research. Much of my understanding of these problems arises from long discussions with him.

reviewed, emphasizing their possible uses for planning; next, the basic model selected for our purpose is developed; and finally, the regular growth paths for our basic model are explored. 1/ The viewpoint taken here is that a planner can gain insight into the growth process by general analysis of a model; but for specific planning applications a model must be adjusted to features peculiar to the country involved.

In the following analysis it is assumed that growth takes place because capital accumulates. We do not discuss problems of the optimum use of capital nor growth which arises from better administration, education of the labor force, etc. We recognize that the realism of this viewpoint has been challenged and that a substantial amount of growth takes place for reasons other than capital accumulation. Yet, the whole framework of aggregative economic analysis has progressed very little beyond putting the burden of growth on the accumulation of capital, and the type of model developed here does not go beyond this approach. The reasons for this narrow scope are familiar; output must be expressed through a production function or related concept to variables describing inputs from the economy; once capital and labor and perhaps a time trend in the productivity of the factors are introduced, little more can be done to explain the level of output. Even in the advanced countries attempts to refine the concept of labor force to allow for skill levels, or to incorporate measures of the average size of firm to allow for exploitation of economies of scale, or to

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1/ A regular growth path is one characterized by income increasing at a constant rate; i.e.,

$Y(t) = (1+r)^t Y(o)$ where $Y(t)$ is income at time t and r is the constant rate of growth of income.

allow the degree of monopoly to effect the economy are at a rudimentary stage. Attempts to introduce additional explanatory factors, given the poverty of data characteristic of the under-developed countries are rightly discouraged. It should also be noted that placing capital in a central role is appropriate for analysis of particular development problems, and thus this justification would appear to apply to a model developed for relating capital imports and associated debt service.

The question of causality is also pertinent to this issue. The interrelated nature of an economic system makes extremely dubious the assertion of causal phenomena. In fact, one is never really sure what causality means when the system is unique and inexorably linked to the past. The statement that growth takes place because of capital accumulation is a simplified statement of a complex idea. We do not ascribe true causality to any single factor; the model as a whole is interrelated, and a change anywhere will affect the growth of output. One says that capital accumulation causes growth only in the sense that the increase in the capital stock is the immediately prior condition to be fulfilled before output increases. The assumption can be restated: Growth takes place when capital accumulation takes place, but there is no assertion that one causes the other. The rate of capital accumulation may increase because of some consideration far removed from the saving-investment relation. Accumulation of capital is a central part of the model developed here, but the validity of the formulation does not depend on the assumption that capital accumulation is the only source of growth. It suffices to assert that capital accumulation takes place with growth.

Our central problem is particularly relevant to a class of economic systems with certain functional properties. These functional characteristics include the following: (1) The balance of payments is a major constraint during development. (2) The supply of domestic saving is likely to be dependent on the level of exports. (3) Government revenues are tied to the foreign trade sector, and consequently, the capacity of the government to absorb inter-governmental loans is dependent on the behavior of components of the balance of payments. (4) The importance of the balance of payments constraint makes it difficult to mobilize internal resources through inflationary policies. (5) For these reasons, foreign capital tends to be an important source of investment finance, and the resulting debt service problem becomes a major constraint for both the balance of payments and domestic investment.

It is our view that these functional characteristics are most clearly exhibited by small, open economies. By a small country is meant one with a population on the order of five million or less. 1/ By an open economy is meant one which has developed a substantial amount of foreign trade. In the course of development, primitive societies begin to modernize with a growing interaction with other societies; such interactions may take many forms, but among the most important is the growth of foreign trade. Thus, a very primitive small country is not relevant here; the characteristic of "openness" implies that some development has taken place, and that exports represent a relatively large part of total domestic product.

1/ Out of some 91 underdeveloped countries or identifiable territories, 51 were in this class in mid-1962. (Information Service, Population Reference Service)

The identification of small countries with the above functional characteristics requires elaboration. A small country must inevitably depend on imports much more than does the large country for two reasons. First, many types of products require minimum scales of output for efficient production, and many will be larger than the small country's market can support. Secondly, since there is a general correlation between natural resources and geographic area on the one hand and between population and geographic area on the other, the variety and volume of natural resources available to small countries is generally severely limited relative to larger countries. Hence, we find small countries to be dependent on imports for raw materials and intermediate goods as well as for finished goods for economies of scale reasons. This great dependence on imports makes the balance of payments a vital factor in growth. It limits the ability of the small country to pursue autarkic development policies. Thus, exports are vital, and import substitution strategies are delicate, requiring precise identification of feasible industries.

As implied above, the limits of foreign exchange and financial policy are narrow for small countries. Currency restriction, quota, and tariff policy must be used with extreme caution, since the impact of such controls is direct and critical. Inflation as a source of financing government expenditures is a dangerous policy since the results will tend quickly to force an equivalent devaluation or cause the economy to stagnate through an inability to import. For this reason as well as the link between government revenues and foreign trade, mobilization of domestic saving through government effort is subject to tighter constraints than for larger, more diversified economies. It is likely, therefore, that foreign capital, either through development assistance or through private foreign investment, will play a

more vital role (compared to domestically financed investment) in the development of small countries than of large ones.

This dependence on foreign capital first affects the balance of payments by making foreign exchange resources available and later by withdrawing resources as profits are transferred or debt service on loans is undertaken. When substantial amounts of foreign capital are introduced within a short period of time, the consequence is rapidly expanding debt service obligations, in the context of already great foreign exchange requirements on current account. In short, the difficulty is that excessively rapid development imposes both high import requirements and high debt service charges in future years.

The literature on international trade theory has discussed in great detail the so-called "transfer problem." That is, if Country A owes Country B (regardless of how the debt came to exist), how can Country A "pay" its debt? The payment must take place in real resources, which means goods and services must be made available to Country B. Whether this is done directly by exports or indirectly by exports to a third country which, in turn, exports to Country B is irrelevant. Country A must obtain currency (a proxy for real revenues) acceptable to Country B, and this means either exporting or borrowing. The discussion as to how this repayment could take place has usually revolved around changes in the price level <u>or</u> changes in income. It is clear that both effects exist and are of importance. Following the recent tradition in this field, however, our model will place stress on income effects; hence, price parameters will not be introduced.[1/] However, domestic price adjustments will not be treated as a method of correcting balance of payments disequilibrium since such adjustments require overall policy changes. Since exchange rate variations are subject to severe

1/ Prices will be incorporated into the model in a future working paper.

constraints, the only price that turns out to be significant is the wage rate. With the cost of capital strongly influenced by external factors, and given the technology, the wage rate basically determines the production costs of both export and domestically produced import-competing goods. If price effects were to be introduced, therefore, it would be appropriately done through the mechanism of wage rate adjustment. However, this is not attempted in the present paper.

As applied to development planning, aggregative or macro-models have a very precise use. The model relates parameters and variables which describes the economy. Variables in a macro-model can be divided into two classes: Exogenous variables whose time specific values are arrived at from considerations external to the model; and endogenous variables whose values are given by the model once the endogenous variables and the parameters are specified. The parameters of the model can be conveniently divided into two classes: Those whose values are fixed and those which are sensitive to policy actions by the government. Members of this latter class are called "policy parameters" or using Tinbergen's terminology, "instrument variables." There is some correspondence between the "policy parameters" and administrative action of the government. In fact, one of the purposes of an aggregative planning model is to supply guidance for improving administrative actions.

The solution of an aggregative model can proceed in two ways: First, there is the forecasting solution which proceeds in the following manner. The exogenous variables and all of the parameters of the system are given (usually estimated from appropriate data) and the values of the endogenous variables determined. If some parameters are "policy parameters" then the forecaster has to make his best guess as to what values such parameters will

take on. Second, there is the planning solution. In the planning solution values of some of the endogenous variables are specified. These specified endogenous variables are called "policy objectives" or targets. The exogenous variables, the specified endogenous variables (targets) and the given (non-policy sensitive) parameters are used to solve the model for the remaining endogenous variables and the "policy parameters." In actual planning operations, the political leadership usually specifies the policy objectives and the planner then does two things. He determines the values of the "policy parameters," and then outlines the appropriate administrative actions needed to achieve the "policy parameters." The effect of the macro planning model is thus to limit the number of endogenous variables whose values can be set as objectives or targets. This framework (which closely follows the Tinbergen-Theil formulation) must be kept in mind to understand the following analysis.

A caveat is in order on data questions. A planning model of great complexity is of little value in most less-developed countries because the data is of such uncertain quality. Complexity requires repeated combination of data, and so the size of the errors grows. A useful model must be simple enough to make valid statements over meaningful periods of time. This observation leads to a strong argument to avoid excessive disaggregation and to avoid excessive complexity in the model describing the economy. Yet the model approach cannot really be avoided; its essential characteristic is to account properly for the multiple interrelations between parts of the economy. This simplified general equilibrium approach enables the analyst to specify precisely the assumptions that he makes and present these assumptions in a way which makes it easy to test their empirical validity. This is why the model approach must ultimately be the planner's fundamental tool. It becomes, in

essence, a device to be sure that the most important considerations have been taken into account.

From this last observation it follows that progress in model-building takes place because we recognize considerations, important in the real world, which are neglected in existent models. Thus, development planning models usually account for the interaction between growth (through capital accumulation) and balance of payments equilibrium by relating imports to the level of output and possibly to its composition. However, to the extent that investment is financed from foreign sources, the country "contracts" to transfer resources abroad in the future. It is this additional consideration which is studied herein. Still another interconnection arises from the government's responsibility to repay loans from foreign sources and the increase of government revenues. The ability to borrow in this wider sense depends then on the response of government revenues and of balance of payments components to growth. In this first study, only the debt service problem is considered; the second problem will be discussed in subsequent work.

The growth of an economy can be connected with the balance of payments through several mechanisms. For example, saving may be greater when exports are a high percentage of national product; the level of foreign reserves may be built up or run down; in a dual economy export growth may induce more rapid movement of labor from the subsistence to the money sector; the private sector demand for investment may be affected by the rate of growth of exports; and finally, the amount of domestic saving transferred abroad may be affected by the rate of growth of the economy or exports. Considerations such as these are likely to be relevant for models descriptive of a particular economy; however, only brief treatment will be made of these

possibilities in the general framework of this paper. The Center's work on particular economies will take cognizance of the importance of such special features, where appropriate.

The following discussion consists of three parts. First, we present a series of models of increasing scope designed to introduce the role of foreign capital and international trade into a simple growth model. Second, the framework of the basic debt service-profit transfer model is discussed in detail. Finally, some simple solutions of the debt service-profit transfer model are studied, and from this rules of thumb are developed for relating parameters of the economy to one another.

I. ANALYTICAL BACKGROUND: A SEQUENCE OF MODELS

To better understand the framework for the debt service-profit transfer model, introduced in Section II, we proceed by reviewing a sequence of models, each involving an additional aspect of the development problem relevant to the framework used here. The first model is the closed Harrod-Domar model in which growth is constrained only by capital accumulation. The second model is the open Harrod-Domar model within the constraint of utilization of capital. In the third, also an open Harrod-Domar model, the full utilization of capital constraint is relaxed and foreign exchange reserves occupy an important role. The fourth model introduces foreign saving only as a source of financing capital accumulation. Finally, the fifth model combines foreign saving with a balance of payments constraint. Models three and five are developed in some detail since they throw light on the role of exports in development, a central phenomenon in the debt service-profit transfer model.

A. Closed Economy Harrod-Domar Model

The simplest growth model considered is the Harrod-Domar model containing no international sector. It consists of four relationships:

1.1a) $Y = kK$ (production condition)

where Y is real output, K is capital stock, and k is the productivity of capital (the inverse of the capital-output ratio).

b) $S = \alpha Y$ (aggregate saving function)

where S is aggregate savings and where α represents the average and the marginal saving rates which are equal for this saving function.

c) $\Delta K = I$ (stock-flow relationship between capital stock and investment)

where I is investment, and depreciation is neglected for simplicity.

d) $Y = C + I = C + S$ (national income accounting system)

where C is consumption. These equations can be summarized as the investment-saving identity and the definition of consumption as a residual.

All of the more complex aggregate single sector models will, in fact, be found to contain these four types of relations. The solution of the Harrod-Domar model is well known: All variables grow at a constant rate from <u>any</u> initial level by a rate αk; i.e., the saving rate times the productivity of capital. The Harrod-Domar model, as outlined here, operates on the assumption that there are no other scarce factors limiting growth except capital. That is, all other inputs, e.g., skilled labor, entrepreneurship, unskilled labor are in excess supply and remain so throughout the period of the analysis.[1/]

B. <u>Open Harrod-Domar Model</u>

If foreign trade enters the model only through exports (E) and imports (M), then the model must be appropriately adjusted. Two alternative cases can be considered: (1) the balance of payments must be in equilibrium

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1/ The original Harrod formulation of the model certainly made such an assumption since the analysis is directed at unemployment situations in developed countries. This is not a bad assumption if one is attempting to determine saving requirements to obtain a target rate of growth if the target rate of growth was obtained by study of, or appears consistent with, resource availabilities of other factors.

or (2) a maximum deficit in the balance of payments is established. In case (1) the model is expanded by adding the balance of payments equilibrium equation:

$$1.2)\ E = M$$

where E represents exports and M imports. In case (2) the saving-investment equation becomes

$$1.3)\ I + E = M + S$$

and the balance of payments constraint is given by an inequality

$$1.4)\ M - E \leq D$$

where D is the exogenously given maximum. Normally, one would relate imports to the level of output or to the composition of income expenditures (consumption, investment, exports). The consequence of introducing the international sector is to suggest the share of output which must be devoted to exports. Let

$$1.5)\ M = m_1C + m_2I + m_3E$$

where m_1, m_2, and m_3 are import coefficients of consumption, investment, and exports, respectively. Since C, I, and Y all grow at the Harrod-Domar rate, αk, the proportions of output spent on investment, consumption, exports, and imports can now be found. For case (1), equation (1.5) implies:

$$1.6)\ M - m_3E = m_1C + m_2I$$

and since,

1.7a)	$M = E$	(equation 1.2)
b)	$I = S = \alpha Y$	(equations 1.1d and 1.1b)
c)	$C = Y - I$	(equation 1.1d)
d)	$C = Y(1 - \alpha)$	(from equations 1.7b and 1.7c)

one obtains:

$$1.8)\ E(1 - m_3) = m_1(1 - \alpha)Y + m_2\alpha Y \text{ (from 1.7a, 1.7b, and 1.7d)}$$

so that:

$$1.9)\ \frac{E}{Y} = \frac{m_1(1 - \alpha) + m_2\alpha}{1 - m_3}$$

That is, the required proportion of exports to output is a weighted average of the import coefficient of consumption and the import coefficient of investment divided by export earnings net of imports for export production. Exports must stay at this proportion of total output if the economy is to grow at the specified rate, αk, while balance of payments equilibrium is maintained.

For case (2) the maximum deficit of the balance of payments is given by

$$1.10)\ D = M - E \text{ or } M = E + D$$

Using this relationship, the minimum ratio of exports to output is: 1/

$$1.11)\ \frac{E}{Y} = \frac{m_1(1 - a) + m_2 a}{1 - m_3} - \frac{D}{Y(1 - m_3)}$$

The planner must be sure that the level of exports stays between the

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1/ Since $M = E + D$

$$E(1 - m_3) + D = (m_1(1 - \alpha) + m_2\alpha)Y$$

then

$$\frac{E}{Y} = \frac{m_1(1 - \alpha) + m_2\alpha}{1 - m_3} - \frac{D}{Y(1 - m_3)}$$

maximum required proportion (equation 1.9) and the minimum required proportion (equation 1.11). Exports must fall within this range if the economy is to grow smoothly and balance of payments equilibrium is to be maintained.

C. Open Harrod-Domar Model with Unutilized Capital

We introduce another complexity by asserting that the level of exports is given exogenously while continuing to assume no foreign capital flows. If import demand at full utilization of capital stock exceeds the volume of imports that can be financed by current export earnings, adjustment will be necessary. Since price adjustments are not possible by assumption, either reserves must fall or imports must be cut back by income falling below the level associated with full utilization of capital. We now proceed to demonstrate the calculation of the period of time that will elapse before under-utilization of capital commences.

Let the utilized capital stock be $\hat{K}$ so that the production function is now written:

1.12.a) $Y = k\hat{K}$ and

b) $\hat{K} \leq K$

i.e., utilized capital stock is less than or equal to the total capital stock available. We can write the balance of payments equilibrium as:

1.13) $E = M + \dot{R}$

where $\dot{R}$ is the change in the level of reserves. Furthermore, we specify a lower limit to R given by:

1.14) $R \geq nM$

That is, the level of reserves must be n times the level of annual imports.[1/] Let us begin with the case where the economy is fully utilizing its capital stock, $K = \hat{K}$ and the actual level of reserves is above the minimum:

$$1.15.a)\quad R(0) = \gamma n M(0) \quad \text{or}$$

$$b)\quad \gamma = \frac{R(0)}{nM(0)}$$

i.e., γ is a parameter measuring the ratio of the initial actual level of reserves to the initial minimum level. Hence, it is clear that $\gamma > 1$. Exports are exogenous to the system (by assumption) and are given by $E = E(0)e^{\lambda t}$. The expression represents $E(0)$, the initial level of exports, and λ is the rate of growth of exports. Then substituting the exogenous expression for exports, we have:

$$1.16)\quad E(0)e^{\lambda t} = M + \dot{R}$$

The saving investment equality gives: [2/]

$$\dot{K} = \alpha k K$$

where $\dot{K}$ is the rate of change of capital stock. This growth equation implies

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1/ Reserves are held for transactions and precautionary motives. That is, some reserves are held to facilitate the financing of imports since receipts from exports and expenditures for imports may be timed differently, resulting in the need to carry foreign exchange reserves to avoid payments difficulties. The precautionary reason includes guarding against such factors as a temporary failure of the export producing sector and short-term fluctuations in export prices.

2/ Since depreciation is neglected here, the rate of change of capital stock equals the level of investment equals the level of saving; i.e., $\dot{K} = I = S$. Therefore, from the production condition (equation 1.1a) and the saving function (equation 1.1b), $\dot{K} = S = \alpha Y = \alpha k K$.

that output (Y) and capital stock (K) will grow at the same rate (αk). Then:

$$1.17.a)\quad K = K(0)e^{\alpha kt}$$

$$b)\quad Y = Y(0)e^{\alpha kt}$$

and if the demand for imports is:

$$c)\quad M = mY$$

then

$$d)\quad M = M(0)e^{\alpha kt}$$

Hence, the change in reserves is given by:

$$1.18)\quad \dot{R} = E(0)e^{\lambda t} - mY(0)e^{\alpha kt}$$

Integrating:

$$1.19.a)\quad R = \frac{E(0)e^{\lambda t}}{\lambda} - \frac{mY(0)e^{\alpha kt}}{\alpha k} + N$$

where N is a constant. At t = 0:

$$b)\quad N = R(0) - \frac{E(0)}{\lambda} + \frac{mY(0)}{\alpha k}$$

Substituting equation (1.15.b) in the above, we find that the level of reserves is:

$$1.20)\quad R = \frac{E(0)}{\lambda}(e^{\lambda t} - 1) - \frac{mY(0)}{\alpha k}(e^{\alpha kt} - 1) + \gamma nmY(0)$$

If $\dot{R} < 0$, i.e., if reserves are being reduced, then when $R(t) = nM(t)$, no further running down of reserves can take place. This occurs at time $t = T$. The following equation can be solved for T:

$$1.21)\quad nmY(0)e^{\alpha kT} = \frac{E(0)}{\lambda}(e^{\lambda T} - 1) - \frac{mY(0)}{\alpha k}(e^{\alpha kT} - 1) + \gamma nmY(0)$$

The solution of this equation for T, given an initial excess reserve ratio, γ, and a minimum reserve ratio, n, tells how long it takes before reserves are run down to the minimum level. After time T, it is no longer possible for reserves to change; i.e., $\dot{R} = 0$, and the level of output is now

determined by the balance of payments equilibrium condition, $M = E$, so:

$$1.22.a)\quad mY(t) = E(t) = E(0)e^{\lambda t} \qquad \text{for } t \geq T$$

$$b)\quad Y(t) = \frac{E(0)}{m} e^{\lambda t} \qquad \text{for } t \geq T$$

The utilized capital stock is then found from the production condition (equation 1.12.a):

$$1.23)\quad \hat{K}(t) = \frac{E(0)}{mk} e^{\lambda t} \qquad \text{for } t \geq T$$

and saving is found from the saving function (equation 1.1b):

$$S(t) = \frac{\alpha E(0)}{m} e^{\lambda t} \qquad \text{for } t \geq T$$

Thus, after time T has been reached, the rate of growth of the economy is controlled by the rate of growth of exports (λ). Output, utilized capital stock, and saving all grow at the rate λ. The total stock of capital is then the stock of capital at time T plus all saving from T to the present: 1/

$$1.24.a)\quad K(t) = K(T) + \int_T^t S(\tau)d\tau$$

$$b)\quad K(t) = K(T) + \int_T^t \frac{\alpha E(0)}{m} e^{\lambda\tau}d\tau = K(T) + \frac{\alpha E(0)}{\lambda m}(e^{\lambda t} - e^{\lambda T})$$

The ratio of available capital to utilized capital is:

$$1.25)\quad \frac{K(t)}{\hat{K}(t)} = \frac{K(T) + \frac{\alpha E(0)}{\lambda m}(e^{\lambda t} - e^{\lambda T})}{\frac{E(0)}{mk} e^{\lambda t}}$$

Since at T the stock of capital is fully utilized:

$$1.26)\quad K(T) = \hat{K}(T) = \frac{E(0)}{mk} e^{\lambda T}$$

1/ The $\int_T^t S(\tau)d\tau$ is a symbol to stand for adding up all saving from time T to time t (the present). τ is a dummy index.

Hence:

$$1.27)\quad \frac{K(t)}{\hat{K}(t)} = e^{-\lambda(t - T)}(1 - \frac{\alpha k}{\lambda}) + \frac{\alpha k}{\lambda} \qquad \text{for } t \geq T$$

As t increases, the first term decreases in absolute magnitude (it is negative if $\alpha k/\lambda > 1$, i.e., exports grow less quickly than the Harrod-Domar rate, αk) and $K(t)/\hat{K}(t) \rightarrow \frac{\alpha k}{\lambda}$ as t becomes very large, or $\hat{K}(t)/K(t) \rightarrow \lambda/\alpha k$. This means that if the economy is in a position of balance of payments deficit and reserves cannot be reduced any further, then it is exports which dominate growth. In a planned economy in which capital accumulation may proceed despite the presence of unutilized capital stock, the ratio of utilized to unutilized capital stock is given by the ratio of the rate of growth of exports (λ) to the natural Harrod-Domar growth rate (αk).

In the special case in which exports do not grow at all, $\lambda = 0$. Output, saving, and utilized capital stock are all constant, whereas capital stock continues to grow. Capital stock is given by:

$$1.28.a)\quad K(t) = K(T) + \frac{\alpha E(0)}{m}(t - T) \qquad \text{so that}$$

$$b)\quad \frac{K(t)}{\hat{K}(t)} = 1 + \alpha k(t - T)$$

Hence, the ratio of utilized capital stock to total capital stock is:

$$c)\quad \frac{1}{1 + \alpha k(t - T)}$$ which decreases indefinitely as time passes.

Analytical Implications

To recapitulate the argument in this section, in which we allow the possibility of unutilized capital stock but continue to exclude foreign capital flows, the Harrod-Domar growth rate (αk) dominates until reserves reach their minimum level (defined here in terms of imports). Then output

can only grow as fast as imports, and imports can only grow as fast as exports. Capital is accumulating at the Harrod-Domar rate (αk); and if exports grow more slowly than the αk rate (a condition necessary to run reserves down to the minimum level), then there will be unutilized capital in the economy. In an economy responsive to market demand for investment, accumulation of excess capacity would reduce the demand for investment and slow down capital accumulation. For a planned economy, however, where the rate of capital accumulation is effectively determined by plan, no such adjustment need take place. Then the rate of income growth is determined by the growth of exports, and the percentage of utilized capital approaches the ratio of the export growth rate to the Harrod-Domar growth rate.

It is further apparent that whenever the projection for exports is adjusted, a shift in the growth path of output will ensue. For example, if exports show a falling-rising-falling-rising rate of growth, then we would expect in the initial period for reserves to be run down towards the minimum acceptable level, and unutilized capital stock might also develop, with the rate of growth of output controlled by the rate of growth of exports. When a rising rate of growth of exports is resumed, the unutilized capital stock would be taken up. When full employment of capital is reached, reserves would begin to accumulate. As export growth slowed down again, reserves would again be run down, excess capacity would again appear, and the rate of output change would again be determined by the rate of growth of exports. A cyclical behavior would appear in the economy, generated by a cyclical behavior in the growth rate of exports. Except for the slack provided by reserves, we observe a clear case of export-dominated growth.

Similarly, endogenous cycles would be possible rather than such exogenous cycles of the type described above. This would occur if we allowed the level of saving to be affected by the amount of unutilized capacity; i.e., the more unutilized capacity, the less saving. Then as the economy developed unutilized capacity, the Harrod-Domar growth rate would fall. Under appropriate conditions it could fall below the exogenous and now constant export growth rate, and the increase of unutilized capacity would stop, and the economy would begin to put to use this unemployed capital. The result would be endogenous cyclical behavior, the floor being provided by the growth of exports. This particular condition is relevant as a description of an unplanned economy or an economy where the private sector investment is substantially uncontrolled. In the case discussed in the paragraph above, cycles appear because the rate of export growth changes (exogenously); in the present case the rate of growth of exports is constant but saving changes endogenously in response to unutilized capacity. Export growth rate behavior of the cyclical type posited for the previous case would amplify the swings of this endogenous cycle.

Planning Implications

The extensive development of this model has been carried out to illustrate two important points: (1) the importance of the level of reserves in models treating the international sector and (2) the importance of relaxing the assumption of full utilization of capital. Some of the important planning implications of the analysis may now be expounded. First, this model can be used to "predict" the length of time until a financial

crisis starts.[1/] This may be a very important consideration for international organizations or for a planning agency attempting to project the balance of payments for the near future. For example, underdeveloped countries often find themselves in short-term financial difficulties which require stabilization programs. A typical program of this kind has three aspects: (1) foreign loans to allow the country to continue imports at an adequate level; (2) austerity measures to cut back the level of imports; and, (3) export promotion measures. In terms of the above model, each aspect of the stabilization program has a specific meaning. A complement of loans act as a one-time change in the level of reserves. The import reduction measures serve to decrease m, the import coefficient, and possibly to change α, the saving rate. The export promotion measures serve to change the forecasted level of exports. In this regard, we must remember that underdeveloped countries whose exports are concentrated in a very few commodities differ from countries with a highly diversified export structure in that measures to increase exports in the former are likely to take a relatively long time to yield results. Consequently, the projection of the balance of payments should allow for gradual progress toward the agreed, new equilibrium path. The simple model presented here allows the planner to calculate the growth path of the economy for different combinations of changes in the reserve level, the export projection, and the demand for imports, as well as for a variety of policy alternatives for each.

1/ A financial crisis would cause unutilized capital stock to appear in the economy, and it could not be corrected by increasing effective demand because the balance of payments would be out of equilibrium.

Secondly, this model can serve to indicate the necessary target level for the export expansion program and to indicate the effects of the terms of trade on economic development. As formulated, the model would reflect an expected change in the terms of trade if the exogenous export projection were made in terms of import capacity rather than simply in export value terms. Cyclical variations in the terms of trade would induce cyclical behavior in the growth rates by the implied cyclical variation in the rate of growth of exports. The simple rule of thumb arising from this model is that the rate of growth of exports (import capacity) should be equal to the rate of growth of output. This rule is valid assuming the simple import function ($M = mY$). If more complex linear import functions describe the import behavior of the economy, then the rule of thumb is the same although the consequences of adjustment to insufficient export will be different.

D. "Foreign Aid" Model I: Foreign Savings in a Closed Economy

We return to the case where there is no foreign sector (i.e., no exports or imports), but we introduce foreign saving (S_f). Then, using the previous notation, the saving investment equation becomes: 1/

$$1.29)\quad I = \dot{K} = \alpha kK + S_f$$

We first assume that the level of foreign saving is given (the "aid availability" assumption), i.e.:

$$1.30)\quad S_f = S_f(0)e^{\lambda t}$$

where λ is the rate of growth of foreign saving and $S_f(0)$ is the level of

1/ Total saving equals $\alpha kK + S_f$; hence, $\dot{K} = I = S = \alpha kK + S_f$.

foreign saving at time $t = 0$. The stock of capital grows as: 1/

$$1.31)\ K(t) = [K(0) - \frac{S_f(0)}{\lambda - \alpha k}]e^{\alpha kt} + \frac{S_f(0)}{\lambda - \alpha k} e^{\lambda t}$$

This describes the economy but doesn't tell the planner very much. Output is easily found from the production function, $Y = kK$. Now the growth path of capital (or output since they are proportional) is given by a combination of two regular growth paths, one associated with the Harrod-Domar growth rate (αk) and the other with the growth rate of foreign saving (λ). There are two distinct cases; the first, foreign saving-dominated growth and the second, domestic saving-dominated growth.

(1) Foreign Saving-Dominated Growth. Here $\lambda > \alpha k$; i.e., foreign saving grows at a rate larger than the Harrod-Domar rate. Therefore, the coefficient of the λ growth term, $\frac{S_f(0)}{\lambda - \alpha k}$, is positive, and the coefficient of the αk growth term may be positive or negative depending on the size of:

$$[\frac{K(0)}{S_f(0)} - \frac{1}{\lambda - \alpha k}]$$

If the initial level of foreign saving is high compared to stock of capital and the rate of growth of foreign saving is quite close to the Harrod-Domar rate, then the coefficient can be negative; whereas, if the level of foreign saving is small at the beginning ($S_f(0)$ small), then the coefficient will

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1/ See Appendix I, Paragraph 1. This solution is not valid when $\lambda = \alpha k$. In this latter case, the solution is very simple; i.e.:

$$K(t) = [K(0) + S_f(0)]e^{\alpha kt} - S_f(0)$$

So the economy approaches the long-run growth rate αk, the rate of growth falling from some initial rate towards αk.

tend to be positive. The consequences of negative and positive coefficients are discussed immediately below. We characterize these sub-cases as (1) "big start-slow growth" (αk growth term coefficient negative); and (2) "little start-fast growth" (αk growth term coefficient positive).

(2) Domestic Saving-Dominated Growth. Here $\lambda < \alpha k$; i.e., the rate of growth of foreign saving is less than the Harrod-Domar growth rate. Then the coefficient of the αk growth term is positive and the coefficient of the λ growth term is negative. These alternatives can be described in terms of growth paths on Diagrams I and II. Diagram I, for the foreign saving-dominated growth case where $\lambda > \alpha k$, shows a regular growth path with growth rate λ. This is the long-run path which is approached by the economy. Line (1) on Diagram I is for an actual growth path approaching from above the long-run growth path (λ) and corresponds to the "little start-fast growth" sub-case. Here, foreign savings accelerate the growth rate of the economy. Line (2) on Diagram I is for an actual growth path approaching from below the long-run growth path (λ) and corresponds to the "big start-slow growth" case. The actual rate of growth of the economy is slowing down, despite foreign savings. In Diagram II, representing the domestic saving-dominated growth case, the long-run growth path is described by the αk line. Here, there is only one actual growth path describing the economy, and that is line (1) which is a path approaching the αk line from below, corresponding to a decreasing rate of growth.

Abandoning the "aid availability" assumption, we could alternatively specify a target growth rate, η, and the required level of foreign aid can be calculated. This is only meaningful if the marginal saving rate somehow increases and rises above the average savings rate. If this is not true

DIAGRAM I

GROWTH PATHS FOR FOREIGN SAVING DOMINATED GROWTH

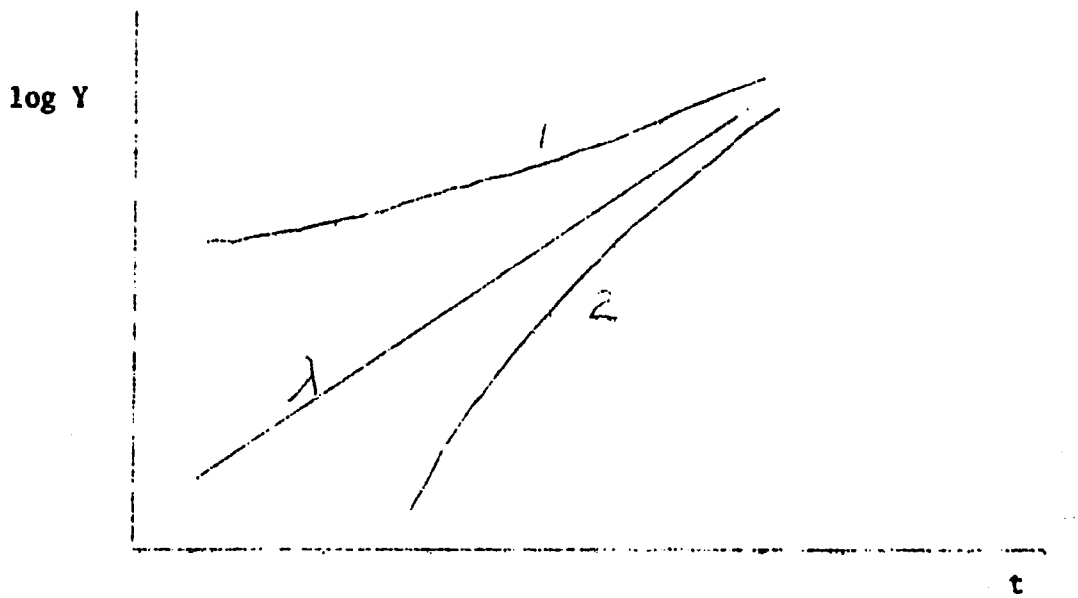
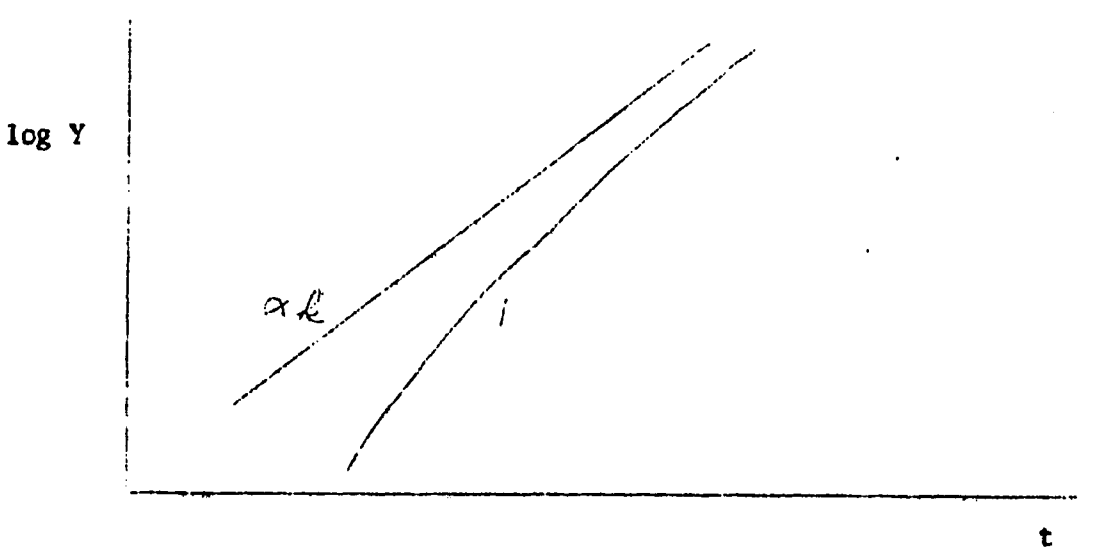


DIAGRAM II

GROWTH PATHS FOR DOMESTIC SAVING DOMINATED GROWTH



[The y axis is the logarithm of output. The x axis is time.
Straight lines represent growth paths with a constant rate of growth.]

and the target growth rate is above the Harrod-Domar growth rate αk, foreign savings must increase indefinitely. If the target is equal to or lower than αk, obviously there is no need for foreign savings. Models with increasing marginal savings rates are very important for planning purposes, since they capture the essential point that if growth takes place through capital accumulation, then only if the rate of domestically-generated capital accumulation increases can the economy approach self-sustaining growth.[1/]

E. "Foreign Aid" Model II: Foreign Savings in an Open Economy

We now proceed to expand the above foreign aid model extended to include the international sector. This requires the introduction of the balance of payment equation:

$$1.32)\ M = E + S_f$$

i.e., imports equal exports plus foreign saving inflow. (It is assumed here that reserves are constant.) The saving-investment relationship remains as in Foreign Aid Model I:

$$1.33)\ I = \dot{K} = \alpha kK + S_f$$

Suppose that the demand for imports is given by:

$$1.34)\ M = mY = mkK$$

then, assuming full utilization of capital, the model has one degree of freedom. The system immediately reduces to:

$$1.35)\ \dot{K} = (\alpha k + mk)K - E$$

1/ See John C. H. Fei and Douglas S. Paauw, "Foreign Assistance and Self-Help: A Reappraisal of Domestic Finance," Development Planning Project, NPA, December, 1963 (mimeographed).

This equation is essentially the same as for the first foreign aid model except that α, the marginal saving rate (equals the average saving rate), has been replaced by $(\alpha + m)$ where m is the marginal propensity to import. Before the growth paths of the model can be determined, another relationship must be specified. There are three alternative ways to do this: (1) specification of the target rate of growth of output, (2) specification of the time path of foreign savings, or (3) specification of the time path of exports. We consider each of these in turn.

(1) If the target rate of growth of output is specified, then the model projects the required ratio of exports to output and the required inflow of foreign assistance. Let η represent the output target so that the time path for growth of output is $Y(0)e^{\eta t}$. Then from the production function $Y = kK$, the time path for capital stock will be:

$$1.36) \quad K(t) = K(0)e^{\eta t}$$

and from equation 1.35, exports are:

$$1.37) \quad E = [(\alpha k + mk) - \eta]K$$

The required ratio of exports to output, $\pi_2 = \frac{E}{Y}$, is:

$$1.38) \quad \pi_2 = \alpha + m - \frac{\eta}{k}$$

The required inflow of foreign saving, S_f, is:

$$1.39.a) \quad S_f = \dot{K} - \alpha kK$$

$$b) \quad S_f = (\eta - \alpha k)K$$

$$c) \quad S_f = (\frac{\eta}{k} - \alpha)Y$$

So, the ratio of required foreign saving to output, π_1, is:

$$1.40.a) \quad \pi_1 = \frac{\eta}{k} - \alpha$$

so that 1.40.b) $\pi_2 = m - \pi_1$

or c) $\pi_2 + \pi_1 = m$

In this case, as one would expect, the higher the ratio of foreign saving to output, the less the required exports to maintain a given target growth rate, and, vice versa, the higher the export ratio, the less is foreign saving required. As a simple example, consider an economy described by the following parameters:

$\alpha = .12$ (i.e., the marginal propensity (and average) to save is 12%).

$m = .20$ (the marginal propensity to import is 20%).

$\eta = .05$ (the target rate of growth of output is 5%).

$k = .3$ (the productivity of capital is .3 or the capital output ratio is 3.3).

Then the ratio of exports must be 15% of output and the ratio of foreign saving to output must be 5%.1/

(2) The second alternative is to specify the time path of foreign saving given by $S_f = S_f(0)e^{\lambda t}$. Where λ is the rate of growth of foreign saving, the output path is given by: 2/

1/ Since $\pi_1 = \alpha + m\frac{\eta}{k} = .12 + .20 - \frac{.05}{.3} = .15$

$\pi_2 = m - \pi_1 = .20 - .15 = .05$

2/ See Appendix I, Paragraph 2.

$$1.41)\quad Y = k(K(0) - \frac{S_f(0)}{\lambda - \alpha k})e^{\alpha kt} + \frac{kS_f(0)}{\lambda - \alpha k} e^{\lambda t}$$

The level of exports found from $E = M - S_f = mY - S_f$ (equations 1.32 and 1.34):

$$1.42)\quad E = mk[K(0) - \frac{S_f(0)}{\lambda - \alpha k}]e^{\alpha kt} + S_f(0)\ [\frac{mk}{\lambda - \alpha k} - 1]e^{\lambda t}$$

The ratio of exports to output is then:

$$1.43)\quad \pi_2 = E/Y = \frac{mk[K(0) - \frac{S_f(0)}{\lambda - \alpha k}]e^{\alpha kt} + S_f(0)[\frac{mk}{\lambda - \alpha k} - 1]e^{\lambda t}}{k[K(0) - \frac{S_f(0)}{\lambda - \alpha k}]e^{\alpha kt} + [\frac{kS_f(0)}{\lambda - \alpha k}]e^{\lambda t}}$$

If $\alpha k > \lambda$, the long-run ratio of exports to output is m, since the dominant terms in the numerator and denominator are the coefficients of the αk term and the ratio of the coefficients is m. If $\lambda > \alpha k$ then the long-run ratio is the ratio of the coefficients of the λ term:

$$1.44)\quad \pi_2 \to m + \alpha - \frac{\lambda}{k}$$

The ratio of foreign savings to output:

$$1.45)\quad \pi_1 = \frac{S_f}{Y} = \frac{S_f(0)e^{\lambda t}}{k[K(0) - \frac{S_f(0)}{\lambda - \alpha k}]e^{\alpha kt} + \frac{kS_f(0)}{\lambda - \alpha k} e^{\lambda t}}$$

If $\lambda > \alpha k$ then this ratio approaches the ratio of coefficients of the λ terms; i.e.:

$$1.46)\quad \pi_1 \to \frac{S_f(0)}{\frac{kS_f(0)}{\lambda - \alpha k}} = \frac{\lambda}{k} - \alpha$$

If $\lambda < \alpha k$ then the ratio approaches zero; i.e., $\pi_1 \to 0$

Generally, the inflow of foreign saving will not grow indefinitely at a rate faster than the rate of growth of the economy in the absence of

foreign saving. So it is unreasonable to assume that the $\lambda > \alpha k$ case is realistic. Therefore, restricting ourselves to the $\lambda < \alpha k$ case, at $t = 0$, π_2 is given by:

$$1.47)\quad \pi_2(0) = E^{(0)}/Y_{(0)} = \frac{mkK(0) - S_f(0)}{kK(0)} = m - \frac{S_f(0)}{kK(0)} = m - \pi_1(0) < m$$

In this case, exports must grow in relation to output, since in the long-run, $\pi_1 \to m$. Also, $\pi_2 \to 0$ as foreign saving becomes less and less important. To use this version of the model, the planner compares the expected rate of growth of exports with the required growth and, by so doing, determines if the basic investment program is properly oriented. The initial rate of growth of output is:

$$1.48)\quad \alpha k + \frac{S_f(0)}{K(0)} = \alpha k + k\pi_2(0) = (\alpha + \pi_2(0))k$$

The rate of growth of output is greater than αk when $\lambda < \alpha k$; i.e., when the rate of growth of foreign saving is less than the Harrod-Domar growth rate. As capital accumulates, the rate of growth of output decreases towards αk. This takes place because foreign savings become progressively less important as a source of investment finance.

(3) The third case is specified if exports are projected exogenously so that future exports are given by:

$$1.49)\quad E = E(0)e^{Nt}$$

where $E(0)$ is the initial level of exports and N is the rate of growth of exports. Then the growth of the economy is described by: 1/

1/ See Appendix I, Paragraph 3.

$$1.50)\quad Y(t) = k[K(0) - \frac{E(0)}{mk + \alpha k - N}]e^{(\alpha k + km)t}$$

$$+ \frac{kE(0)}{mk + \alpha k - N} e^{Nt}$$

and the required volume of foreign saving is:

$$1.51, a)\quad S_f = mY(t) - E(t)$$

$$b)\quad S_f = mk[K(0) - \frac{E(0)}{mk + \alpha k - N}]e^{(\alpha k + km)t}$$

$$+ E(0)e^{Nt}(\frac{mk}{mk + \alpha k - N} - 1)$$

For these growth paths, a number of alternative cases are studied in Appendix II.

Whichever of the three procedures for completing the model is used, the model demonstrates the alternative behavior paths. The model operates in such a way that the balance of payments and the saving-investment relationship are in equilibrium. The model treats a growth situation which is reasonable in the sense that the country is attempting to stay on the equilibrium path forecast by the model; it does not explain adjustment to development programs which are not balanced along the equilibrium path.

* * * * * * *

The purpose of this section has been to review a series of models, each reflecting a facet of the growth problem of a small, open economy. This review provides the basis for proceeding to our central problem, that of including debt service, or capital transfer, within a planning framework. As resources are brought in from abroad, there is associated a future transfer back to the rest of the world. This problem is vitally important for development planning, particularly in the case of the small, open economy.

The commitments undertaken for future transfer of resources abroad must eventually be met, but being far in the future they may cause serious difficulty because of neglect in the present. An aggregative framework is needed to center attention on these future implications of present foreign borrowing. We now turn to the development of this framework.

II. THE DEBT SERVICE-PROFIT TRANSFER MODEL

This section describes in detail the model structure used to incorporate the debt service and profit transfer problems. In the following section, conclusions from this analysis are elaborated.

The present section develops the debt service-profit transfer model by presenting three major aspects of the model's structure: (1) the accounting relations, (2) the behavioral relations, and (3) the closure properties.

A. Accounting Structure

There are two accounting structures: first, a national accounts system given for a single time and, secondly, a system allowing intertemporal relations between foreign saving and external transfers, from either profits earned on foreign-owned capital or from debt service requirements.

1. National Accounting System

The following symbols are used as defined:

Y - Gross domestic product

Y^* - National income

C - Domestic consumption

S - Total saving

S_d - Domestic saving

S_f - Foreign saving

E - Exports

M - Imports

I - Total investment

P - Debt service or profit transfer

R - Level of foreign exchange reserves[1/]

Then in the usual way gross domestic product is broken down into its components:

$$2.1)\ Y = C + I + E - M$$

All concepts are expressed in real terms (constant prices), valued in domestic currencies. Gross domestic product, Y, expresses the level of production rather than gross national product, since foreign capital is by assumption a substantial part of total capital. It is assumed throughout that foreign capital is the only foreign factor of production. In consequence, there is no difference between domestic consumption and national consumption. No distinction will be drawn between domestic and national exports and imports. However, imports will be related to domestic product, but this causes no difficulties.

There is no depreciation and no indirect business taxes in the model as formulated here, although this will be corrected later, since it gives a false picture of possible growth rates. In fact, proper treatment of

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1/ ΔR is change in reserves; $\Delta R > 0$ means reserves increase and this acts like an additional import.

depreciation is an important, but neglected, problem in less developed countries. National income is domestic product less payments to foreign factors of production less resources used to accumulate foreign reserves: 1/

$$2.2)\ Y^* = Y - P - \Delta R$$

Reinvestment decisions are not treated independently. Instead the conceptual assumption is that all profits are transferred abroad, and the reinvestment decision is made on the same basis as a decision to invest originally. Thus, the foreign saving variable includes reinvestment. This is not an entirely satisfactory procedure since the desire to invest in terms of plowing back profits may be substantially different from a decision to invest initially. On the other hand, the firm clearly has the choice of reinvesting or transferring profits. This becomes a matter of alternative investment opportunities and is comparable to an original investment.

Balance of payments equilibrium is defined by:

$$2.3)\ E + S_f = M + P + \Delta R$$

The model insists upon balance of payments equilibrium. The essence of the model is the nature of the links of the balance of payments to the productive sector. With high incomes, imports are high; with high levels of foreign saving, income growth is faster; but past foreign saving reduces the present

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1/ Interest payments are clearly a payment to a foreign factor whereas principal repayments might be construed not to be. Repayment is a transfer of ownership corresponding to an investment by national income earners. However, repayment does reduce the resources available for saving or consumption by national factors. Consequently, it is more natural to include principal repayment as a payment to a foreign factor and for convenience it will be so treated. Investment is a real concept in this model, and national investment, taking the form of transferring assets from foreign to national ownership (principal repayment), is not included in investment.

import capacity of the economy by the debt service burden imposed.

The formal sector accounts for this system are presented in Table I.

Table I: Sector Accounts

A. BUSINESS

Consumption	C	Imports	M
Investment	I	Domestic income	Y
Exports	E	National income	Y*
		Foreign capital earnings	P
		Changes in foreign reserves	ΔR

$$C + I + E = M + Y$$

$$\text{and } Y = Y^* + P + \Delta R$$

B. HOUSEHOLD

National product	Y*	Domestic saving	S_d
		Consumption	C

$$Y^* = S_d + C$$

C. SAVING/INVESTMENT

Domestic saving	S_d	Investment	I
Foreign saving	S_f		

$$I = S_d + S_f$$

D. FOREIGN

Imports	M	Exports	E
Foreign capital earnings	P	Foreign saving	S_f
		Changes in reserves	-ΔR

$$E + S_f - \Delta R = M + P$$

To recapitulate, the basic accounting equations used in the model are:

2.4.a)	$Y = C + I + E - M$	(2.1 above)
b)	$I = S_d + S_f$	(see Table I)
c)	$E + S_f - \Delta R = M + P$	(2.3 above)
d)	$Y = Y^* + P + \Delta R$	(2.2 above)
e)	$Y^* = S_d + C$	(see Table I)

The fifth equation follows from the first four (an example of Walras's law), and this insures that there is no redundancy in the accounting system.[1/]

2. Inter-temporal Accounting Relationships

The accounting relationships between debt service and foreign saving are developed in this section. These relationships are essentially compound interest rules. Any particular relationship is dependent on the particular rules for repayment of the lending organization.

The basic accounting relationship between foreign borrowing and debt service is given by:

2.5) $P(t) = A(r,T)\ K_f(t)$

where P(t) is the debt service burden, both principal and interest; and A(r,T) is a term which depends on both the interest rate and the repayment

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1/ Since $Y^* = Y - P - \Delta R$: (from 2.4.d)

$Y^* = C + I + E - M - P - \Delta R$ (from 2.4.a)

$Y^* = C + S_d + S_f + E - M - \Delta R - P$ (from 2.4.b)

$Y^* = C + S_d + (S_f + E - M - P - \Delta R)$ (rearranging)

$Y^* = C + S_d$ (from 2.4.c)

period; and $K_f(t)$ is a factor dependent on past borrowing.

Consider a loan for \$1 made at $t = 0$, a loan to be repaid continuously for T years in regular installments. $A(r,T)$ represents the rate of repayment. The total amount repaid is $TA(r,T)$. Representing the volume of debt outstanding by H, obviously H would be equal to 1 at the outset and 0 after the debt is fully retired; i.e., $H(0) = 1$, $H(T) = 0$. The change in H at any moment is the amount repaid less the portion of that representing interest:

$$2.6) \quad -\frac{dH}{dt} = A - rH$$

where $\frac{dH}{dt}$ is the change in debt outstanding (a minus sign is used because debt is falling). A is the rate at which repayment of principal and interest is being made, and rH is the amount of interest instantaneously paid. Solving this equation for H:

$$2.7) \quad H = Ne^{rt} + \frac{A}{r}$$

where N is a constant for $t = 0$:

$$2.8) \quad 1 = N + A/r$$

so the solution for the level of indebtedness, on an original loan of \$1, after t years is:

$$2.9) \quad H = (1 - \frac{A}{r})e^{-rt} + \frac{A}{r}$$

Select A so that $H(T) = 0$:

$$2.10.a) \quad H(T) = 0 = (1 - \frac{A}{r})e^{-rT} + \frac{A}{r}$$

or

$$b) \quad A(r,T) = \frac{r}{1 - e^{-rT}}$$

The amount being repaid at any time t is:

$$2.11)\ P(t) = A(r,T) \int_{t-T}^{t} S_f(\tau)d\tau$$

i.e., all borrowing for the past T years contributes to present debt service. The total indebtedness, D_f, is given by:

$$2.12)\ D_f(t) = \int_{t-T}^{t} S_f(\tau)[(1 - \frac{A}{r})e^{-r(\tau-T)} + \frac{A}{r}]d\tau$$

Diagram III illustrates the pattern of debt repayment assumed in the discussion above. If a grace period of a specified length, T' years, is allowed, however, the repayment pattern would be similar to that shown in Diagram IV. In this "grace period case," the total debt service is given by:

$$2.13)\ P(t) = r\int_{t-T'}^{t} S_f(\tau)d\tau + A(r,T) \int_{t-T'-T}^{t-T'} S_f(\tau)d\tau$$

The total indebtedness is given by:

$$2.14)\ D_r(t) = \int_{t-T'}^{t} S_f(\tau)d\tau + \int_{t-T'-T}^{t-T'} S_f(\tau)[(1-\frac{A}{r})e^{-r(t-\tau+T')} + \frac{A}{r}]d\tau$$

These equations enable us to state explicitly the relationship between foreign saving, debt service, and total indebtedness.

If there are loans of various interest rates and maturities, then the debt service is a sum of terms similar to those above, one term for each type of loan. At one extreme is the private foreign investment for productive purposes. It is assumed that there is no depreciation and no repatriation of capital so that the total amount of foreign-owned capital, $K_F(t)$, is:

$$2.15)\ K_F(t) = \int_{-\infty}^{t} S_f(\tau)d\tau$$

DIAGRAM III

DEBT-SERVICE PATTERN - REGULAR INSTALLMENTS

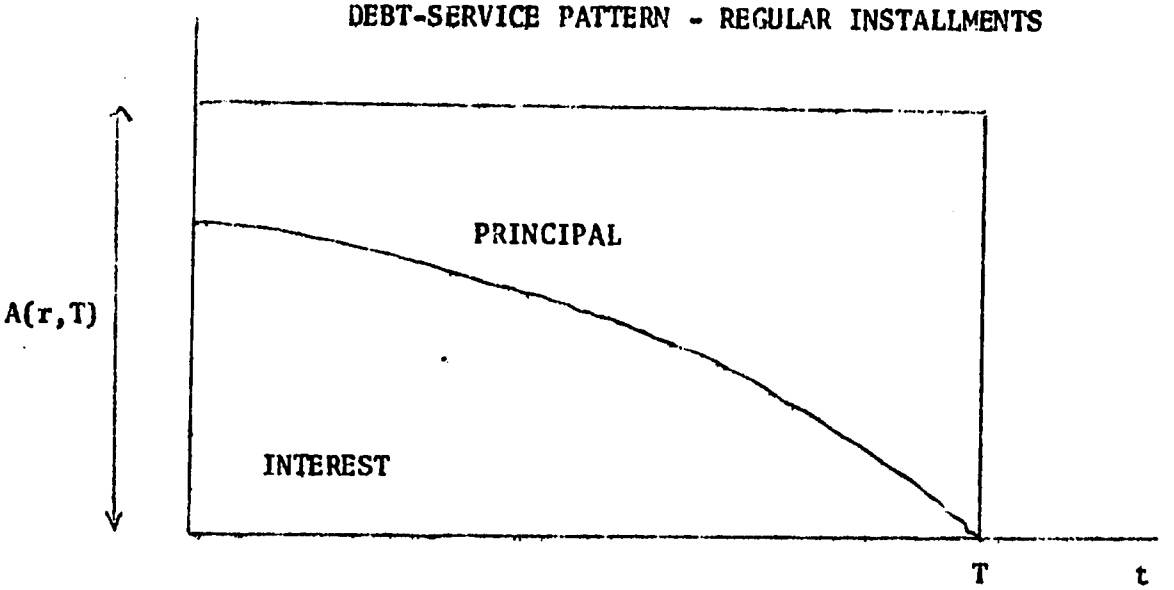
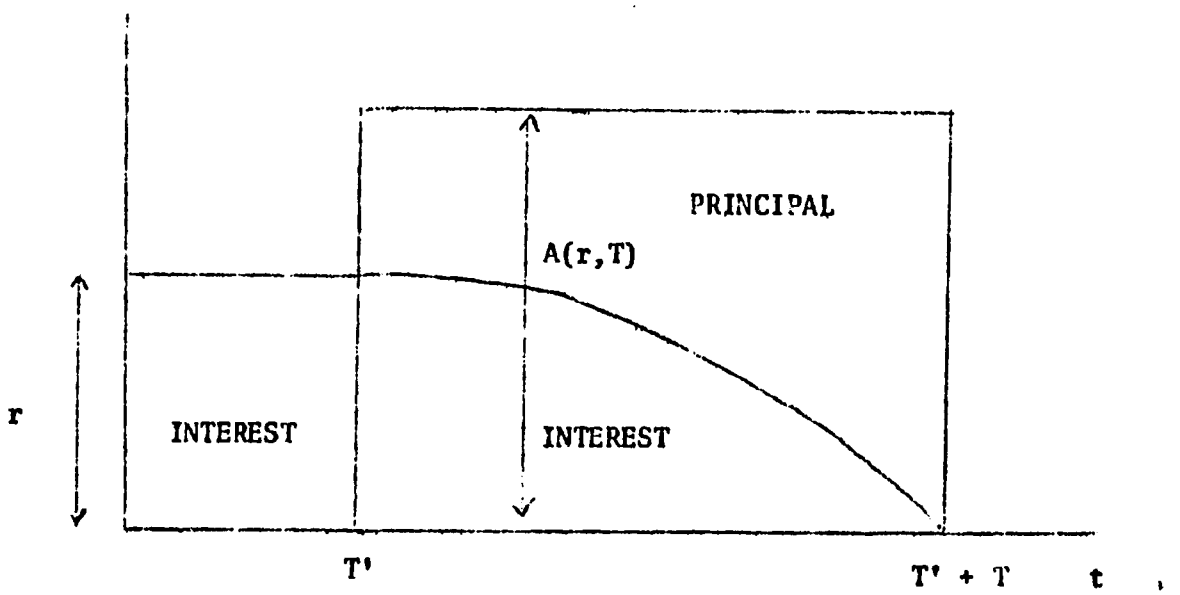


DIAGRAM IV

DEBT-SERVICE PATTERN - GRACE PERIOD FOLLOWED BY REGULAR INSTALLMENTS



Profit transfer is then given by:

2.16) $P(t) = \delta K_F(t)$

where δ , the profit rate, is taken as a parameter.

B. Behavioral Equations

There are three basic behavioral relationships: saving, production, and import. There is also a stock-flow relationship.

Two savings functions are used for somewhat different purposes:

2.17.a) $S_d = \alpha Y$

where domestic savings are proportional to gross domestic product; and

b) $S_d = \alpha Y^*$

where domestic savings are proportional to national income. It should be noted in passing that there is an implicit assumption that no domestic savings are transferred abroad. Debt service and principal repayment have already been accounted.

A production relationship employed in Section I is used:

2.18) $Y = kK$

that is, output is proportional to utilized capital stock. If there is full employment of capital stock, then obviously $K = \hat{K}$. To be realistic, however, we maintain the possibility that the two can diverge, and capital stock not be fully utilized.

We use only the Harrod-Domar type production function, characterized by a constant productivity of capital and for which it is assumed that other factors are not a constraint on growth, since data are rarely available to determine parameters of more complex relationships.

The import function relates imports to gross domestic product:

2.18) $M = mY$

The general import coefficient, m, can be broken down into its components m_1, m_2, and m_3, as we have done in Section II. The specific purpose to which the model is applied and the availability of data for statistical estimation of these coefficients are factors to be considered in choosing whether or not to disaggregate the general import function.

The stock flow relationship connects the stock of capital with investment flows. The amount of saving in a given time period equals the amount of investment since we are dealing with ex post concepts. Then the change in capital stock ΔK equals the volume of saving, as well as investment:

2.19) $\dot{K} = S = I$

where $\dot{K}$ is the time derivative or rate of change of the capital stock. No depreciation is allowed for and so no distinction is necessary between net and gross concepts.

C. Summary of Debt Service-Profit Transfer Model

The full debt service-profit transfer model is repeated here for convenience.

Equations

2.20.a) $Y = C + I + E - M$

b) $Y^* = Y - P$

c) $S_d = \alpha Y^*$ (It has been assumed that the average saving rate equals the marginal saving rate.)

c') $S_d = \alpha Y$

d) $S = S_d + S_f$

2.20.e) $S = I$

f) $I = \dot{K}$

g) $Y = k\hat{K}$

h) $K = \hat{K}$ (assumption of full utilization of capital)

i) $M + P = S_f + E$

j) $M = mY$

k) $P = \delta\int_{-\infty}^{t} S_f d\tau$ (private investment-profit transfer case)

k') $P = A(r,T)\int_{t-T}^{t} S_f d\tau$ (foreign capital-debt service case)

l) $A(r,T) = \dfrac{r}{1 - e^{-rT}}$

Symbols

Y = gross domestic product

C = consumption

I = investment

E = exports

M = imports

Y^* = gross national product

P = transfers abroad (profits or debt service)

S_d = domestic saving

S = total saving

S_f = foreign saving

δ = profit rate on private foreign investment

K = stock of capital

$\hat{K}$ = utilized capital stock

$\dot{K}$ = rate of change of the stock of capital

r = interest rate on foreign borrowing

T = repayment period on foreign borrowing

α = marginal propensity to save = average propensity to save

k = productivity of capital (the inverse of the capital-output ratio)

m = import coefficient

D. Alternative Solutions for Planning Applications: Closure Properties

The model, as specified above, is under-determined. To completely determine the model requires either the addition of structural equations or the specification of an exogenous variable and a description of how the expected values of such a variable are to be determined or some mixture of structural equations and exogenous variables. Choosing one of the alternatives results in closure of the model. In this section, several of the alternative ways of closing the model most relevant for planning in the small, open economy are described. This is not an exhaustive listing; there are several alternatives for closure by other combinations, including the addition of new structural equations.

1. Exports Given Cases

In small, open economies, it is frequently appropriate to assume exports as exogenously determined. Here exports are specified as a function of time. Three sub-cases may be distinguished on the basis of the additional specification required for closure:

(a) Full employment of capital (structural assumption). The model is solved for the growth path of output and the required inflow of foreign capital. This is an interesting case for the planner, since in the

short-run at least, the economy is indeed faced with a given level of outputs. The significant planning question then becomes: Is it reasonable to expect the level of capital inflow required? If not, then three alternatives are possible: first, exports may be increased by adjusting the underlying investment programs towards increased export production; second, unemployment of capital can be allowed to develop; third, imports can be reduced by import substitution or by foreign exchange controls. In the first alternative, the export given case is recalculated on the new assumption about exports. In the second alternative the model closure is described in (b) below. In the third alternative, the export given case is recalculated for a new import function. If, however, foreign exchange controls are utilized without complementary import substitution investments, the effect may be to raise the average saving rate out of real income. (If foreign exchange controls allow capital goods to be imported while restricting consumption goods imports and if the supply response of domestic consumption goods production is sufficiently low, then the prices of consumption goods will be increased. This will raise the amount of real saving since real output of the economy is unchanged and domestic output plus imports of consumer goods are limited.) Then the export given case is studied for the new import and saving functions.

(b) Specification of the expected inflow of foreign savings. For exports and foreign savings specified exogenously, the growth of output is determined. If this growth is not satisfactory, then it is necessary to either (1) change a model parameter, (2) change the expected exports (i.e., rearrange the investment program) or expand foreign savings (e.g., by

searching for more foreign aid or increasing incentives for foreign private investments). The alternative values for the parameters which can be reached through policy may then be studied to determine which provides the most favorable growth path.

(c) Specification of a target growth rate. This, with exports also specified, will determine a level for foreign saving. If this level of foreign saving is not reasonable, then either exports must be increased or the target growth rate decreased.

2. Full Employment of Capital and Target Growth Rate Specified.

This combination determines both required foreign savings and the required level of exports. The relationship between changes in the target growth rate and changes in exports, as well as changes in foreign savings, can be determined. More important, the effect of changes in loan terms (interest rate or maturity) on target growth rates can be calculated.

3. Full Employment of Capital and Foreign Savings Specified.

This model then gives the growth path of output and the required exports.

4. Foreign Savings and Target Growth Rate Specified.

The model will then yield the level of capital utilization and required exports.

These six closure possibilities require selecting any two of the following for specification: foreign savings, exports, the target growth rate, or full employment of capital.

The appropriate closure conditions depend on the particular economy under consideration. The planner must select which of the closure procedures appears most relevant to his problems. If, for example, exports cannot be affected much one way or another but the level of foreign aid is a matter of negotiation, then the appropriate closure procedure would be (1a) which would give the level of foreign savings necessary for full employment of capital. If exports are not given and foreign savings can be negotiated, then procedure (2) can be followed - a target growth rate with full utilization of capital. Then the relationship between the growth rate and the path of foreign savings can be studied.

This completes the presentation of the debt service-profit transfer model. In the following section, the discussion leads in the direction of relating the model to actual planning decisions. While this task cannot be completed in the present paper, a number of "rules of thumb" are developed as broad guidelines to the planner.

III. APPLICATION TO DEBT SERVICE-PROFIT TRANSFER PROBLEMS

The essence of the model presented in Section II is that it expands the traditional Harrod-Domar framework to take account of two important problems in the open economy, the foreign trade problem and the debt service-profit transfer problem. Just as the Harrod-Domar model may be used to provide the planner with convenient rules of thumb relating growth targets and domestic savings requirements, our model can provide, as a first application, broad rules of thumb for planning in an open economy. Applications of this type will be developed in this section in the context of regular growth paths specified by the model.[1/]

In the process of stating the model's regular growth solutions, four fundamental pairs of equations are evolved. These pairs allow the model to handle slightly different assumptions about the domestic savings relation and also to distinguish between two different types of foreign payments associated with past inflows of foreign savings; namely, debt service on past borrowing and profit transfers on past foreign investment.

A. Regular Growth Solutions

In the regular growth solutions, the time path of output is:

3.1) $Y(t) = Y(0)e^{\lambda t}$

where λ is an arbitrary growth rate. If gross domestic product grows at a

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1/ Regular growth paths are defined immediately below. Non-regular growth paths can best be studied in the context of planning for a specific economy; the economic implications of non-regular growth paths are, therefore, less relevant for generalization.

constant rate, all other variables will also grow at this same constant rate.[1/]

1. Fundamental Pair I: Profit Transfer-GDP Saving

The first pair of fundamental equations for solution of the model assumes: (a) that domestic savings depend on gross domestic product (rather than on gross national product), and (b) the private foreign investment - profit transfer case is relevant rather than the foreign borrowing - debt service case.

Two basic equations can be derived from the previous argument:

3.2.a) $\lambda K(0) = \alpha k K(0) + S_f(0)$ [1/] and

b) $mkK(0) + \frac{\delta}{\lambda} S_f(0) = E(0) + S_f(0)$ [2/]

where $S_f(t)$ grows at the rate λ.

The ratio of foreign savings to gross domestic product, π_1, and the ratio of exports to gross domestic product π_2, were defined in Section I.[3/]

1/ For K, this is apparent from equation (2.20g); for I, from (2.20f); for S, from (2.20e); for M, from (2.20j); for S_d, from (2.20c) or (2.20c'); for S, from (2.20d); for P, from (2.20k) or (2.20k'); for Y* from (2.20b).

2/ From (2.20d), (2.20e), (2.20f), (2.20g) and (2.20c'), we know that $\dot{K} = \alpha k K + S_f$. Since $Y = kK$, K will grow at the same rate, λ, as output, so $K(t) = K(0)e^{\lambda t}$. Substituting in the first equation in this footnote gives us (3.2a).

3/ $\pi_1 = \frac{S_f(0)}{Y(0)}$; and $\pi_2 = \frac{E(0)}{Y(0)}$

This allows us to rewrite equations (3.2.a) and 3.2.b) immediately above as:

3.3.a) $\frac{\lambda}{k} = \alpha + \pi_1$ (savings equation)

b) $m + \frac{\delta}{\lambda}\pi_1 = \pi_1 + \pi_2$ (balance of payments equation)

In this form, we refer to the two above equations as Fundamental Pair I. This pair contains seven parameters (λ, k, α, π_1, π_2, δ and m). Specification of any five allows us to solve for the remaining two. Thus, if k, α, δ, and m are given, we can specify π_1 (foreign savings) or π_2 (exports) or λ (target growth rate), and then determine the other two. The three following pairs can also be applied in a similar fashion.

2. Fundamental Pair II: Profit Transfer-GNP Saving

The second fundamental pair for solution assumes: (a) that domestic savings depend on gross national product (which is identical to national income in this model) and (b) that the private foreign investment-profit transfer case is relevant (the same as in Fundamental Pair I).

The basic savings equation, in place of (3.2.a) above, is now:

3.4) $\lambda K(0) = \alpha[kK(0) - \frac{\delta}{\lambda} S_f(0)] + S_f(0)$

using the savings relation given in (2.20.c) rather than the one in (2.20.c'). This can be reduced, by logic similar to reducing (3.2.a) above, to:

3.5.a) $\frac{\lambda}{k} = \alpha + \pi_1(1 - \frac{\alpha\delta}{\lambda})$ (savings equation)

The balance of payments equation for this pair remains the same as in the first case above:

$$\text{b)}\ m + \frac{\delta}{\lambda}\pi_1 = \pi_1 + \pi_2 \quad \text{(balance of payments equation)}$$

Equations (3.5.a) and (3.5.b) then constitute Fundamental Pair II, differing from Fundamental Pair I only in the savings equation. In the latter case, the π_1 in the last term of the savings equation is multiplied by 1, while in Pair II, π_1 is multiplied by $1 - \frac{\alpha\delta}{\lambda}$. This difference arises from using national product rather than domestic product as the source of saving for Pair II.

3. Fundamental Pair III: Debt Service-GDP Saving

The third fundamental pair for solution assumes: (a) that domestic savings depend on gross domestic product (as in Fundamental Pair I), and (b) that the foreign borrowing-debt service case is relevant rather than the private investment-profit transfer case as in Pairs I and II.

The basic savings equation is the same as in Pair I:

$$\text{3.6.a)}\ \frac{\lambda}{k} = \alpha + \pi_1 \qquad \text{(savings equation)}$$

while the balance of payments equation for this foreign borrowing-debt service case is: 1/

$$\text{b)}\ m + \frac{A(r,T)}{\lambda}(1 - e^{-\lambda T})\pi_1 = \pi_1 + \pi_2 \quad \text{(balance of payments equation)}$$

1/ Since:

$$P = A(r,T)\int_{t-T}^{t} S_f(\tau)d\tau = A(r,T)S_f(0)\int_{t-T}^{t} e^{\lambda\tau}d\tau$$

$$= A(r,T)S_f(0)e^{\lambda t}(1 - e^{-\lambda T})/\lambda$$

Equations (3.6.a) and (3.6.b) are Fundamental Pair III. They differ from Pair I only by the changes introduced in the left-hand side of the balance of payments equation from using the foreign borrowing-debt service assumption in place of the foreign investment-profit transfer assumption.

4. Fundamental Pair IV: Debt Service-GNP Saving

The fourth fundamental pair for solution assumes: (a) that domestic savings depend on gross national product (as in Fundamental Pair II), and (b) that the foreign borrowing-debt service case holds (as in Fundamental Pair III).

The savings equation is:

$$3.7.a)\ \frac{\lambda}{k} = \alpha + \pi_1 [1 - \frac{\alpha A(r,T)(1 - e^{-\lambda T})}{\lambda}] \text{ (savings equation)}$$

and the balance of payments equation is the same as in Pair III.

$$b)\ m + \frac{A(r,T)}{\lambda}(1 - e^{-\lambda T})\pi_1 = \pi_1 + \pi_2 \text{ (balance of payments equation)}$$

Equations (3.7.a) and (3.7.b) are Fundamental Pair IV.

The four fundamental pairs, therefore, constitute four slightly different versions of the debt service-profit transfer model to provide flexibility in its application to particular planning situations. It will be observed that each version has two equilibrium conditions, a savings equation and a balance of payments equation. It is this feature of our model which expands the Harrod-Domar type model since the latter utilizes only the savings-investment equilibrium condition. This allows incorporating into our model the critical planning problems posed in an open economy situation.

A summary of equilibrium conditions for regular growth paths in alternative models reviewed in this paper, including the four fundamental pairs just discussed, is presented in Table II. This comparison shows the essential differences in the nature of the several models examined.

B. Application to Planning

Recalling our earlier remarks concerning the use of aggregative models, the significance of the fundamental pairs can now be seen. Consider Fundamental Pair III. In this Pair there are eight parameters (λ, k, α, π_1, π_2, r, T, m). Some of these are policy objectives, some are policy parameters subject to policy control, and some are given. As an example, suppose λ is the target, a policy objective, and that k, r, T, π_1 are given. Then m, α, and π_2 are the policy parameters. However, their possible values are limited. Specification of any one of these three determines the other two through the Fundamental Pair, and the resulting growth path is feasible only if the solved values for the non-specified policy parameters fall with the range of values that are feasible. The exact procedure in applying such a model will depend on the nature of the problem faced by the planner.

The four fundamental pairs may now be applied to show how rules of thumb may be evolved to guide actual planning situations. The demonstration here will consistently use two closure assumptions, the first being full utilization of capital stock. The second closure specification is then to be selected from the three remaining possibilities: foreign savings given, exports given, and target growth rate given. We proceed by considering the case where foreign savings are specified as given. Examples,

applying three of the four fundamental pairs and using these closure assumptions (full utilization of capital and foreign savings given), are provided to demonstrate the utility of the model.

TABLE II

EQUILIBRIUM CONDITIONS FOR REGULAR GROWTH: ALTERNATIVE MODELS 1/

MODEL	SAVINGS EQUATION	BALANCE OF PAYMENTS EQUATION
Closed Harrod-Domar	$\lambda = \alpha k$	None
Open Harrod-Domar	$\lambda = \alpha k$	$m = \pi_2$
Foreign Aid I	$\lambda = (\alpha + \pi_1)k$	None
Foreign Aid II	$\lambda = (\alpha + \pi_1)k$	$m = \pi_1 + \pi_2$
Profit Transfer-GDP Saving (Fundamental Pair I)	$\lambda = (\alpha + \pi_1)k$	$m = \pi_2 + \pi_1(1 - \frac{\delta}{\lambda})$
Profit Transfer-GNP Saving (Fundamental Pair II)	$\lambda = \alpha k + k\pi_1(1 - \frac{\delta\alpha}{\lambda})$	$m = \pi_2 + \pi_1(1 - \frac{\delta}{\lambda})$
Debt Service-GDP Saving (Fundamental Pair III)	$\lambda = (\alpha + \pi_1)k$	$m = \pi_2 + \pi_1(1 - \frac{A(r,T)}{\lambda}(1-e^{-\lambda T}))$
Debt Service-GNP Saving (Fundamental Pair IV)	$\lambda = \alpha k + \pi_1 k[1 - \frac{\alpha A(r,T)(1-e^{-\lambda T})}{\lambda}]$	$m = \pi_2 + \pi_1[1 \frac{A(r,T)}{\lambda}(1-e^{-\lambda T})]$

1/ Symbols are defined in the text.

If the level of foreign saving is given, then the growth rate of the economy and the ratio of exports to gross domestic product can be determined from any of the fundamental pairs. Utilizing first the profit transfer-GDP saving pair (Fundamental Pair I), since the foreign savings ratio, π_1, is given, the growth rate, λ, and export ratio, π_2, are, respectively:

$$3.8.a)\quad \lambda = k(\alpha + \pi_1)$$

$$b)\quad \pi_2 = m + \left[\frac{\delta}{k(\alpha + \pi_1)} - 1\right]\pi_1$$

The first equation (3.8.a) simply says that the growth rate is given by the productivity of capital k, times the total saving ratio, $\alpha + \pi_1$. This is a natural generalization of the Harrod-Domar rule, which would be written $\lambda = \alpha k$ in our notation. We also see that the profit transfer rate does not affect the growth rate, λ, reflecting the assumption that savings depend on gross domestic product.

Equation (3.8.b) gives the required ratio of exports to gross domestic product. If there were no profit transfers (i.e., $\delta = 0$), then equation (3.8.b) would become:

$$3.9)\quad \pi_2 = m - \pi_1$$

a result which appeared before in Foreign Aid Model II, discussed in Section I. In this case, exports are less than imports so long as capital is flowing into the economy.

However, when profit transfers take place, the situation is changed. Exports will exceed imports when:

$$3.10)\quad \frac{\delta}{k(\alpha + \pi_1)} - 1 > 0$$

i.e., when the profit transfer rate exceeds the growth rate of output.

Since the profit transfer rate, δ, is likely to be higher than the growth rate of the domestic economy, the effects of private foreign investment will promote output growth but increase export requirements. Exports will have to be greater than imports to maintain regular growth.

Consider a numerical example in which an economy is described by the following parameters:

$k = .3$ (the productivity of capital is .3, or the capital-output ratio is 3.3)

$\alpha = .09$ (the ratio of saving to gross domestic product is .09)

$m = .15$ (the ratio of imports to gross domestic product is .15)

$\delta = .10$ (the profit transfer rate on foreign-owned capital stock is 10%)

$\pi_1 = .02$ (the ratio of foreign savings to gross domestic product is .02)

Then, the growth rate is:

$$\lambda = .3(.09 + .02) = .033$$

and the ratio of exports to output is:

$$\pi_2 = .15 + \left(\frac{.10}{.033} - 1\right)(.02) = .19$$

Thus, exports must be 19 per cent of output while imports are 15 per cent. Alternatively, if exports were known to be, say 12 per cent of output, then imports could be only 8 per cent of output for regular growth. This discrepancy exists, as we point out above, since the profit transfer rate exceeds the growth rate of output.

Applying the profit transfer-GNP saving pair (Fundamental Pair II), we note that profit transfers affect <u>both</u> the savings and balance of payments

equation. Given π_1, the solution for the growth rate, λ, is: 1/

$$3.11.a)\ \lambda = \frac{k(\alpha + \pi_1) \pm \sqrt{k^2(\alpha + \pi_1)^2 - 4\pi_1\delta\alpha k}}{2}$$

It is shown in the appendix that for $k > \delta$ both roots are positive. The export ratio, π_2, is now given by:

$$b)\ \pi_2 = m + \pi_1(\frac{\delta}{\lambda} - 1)$$

where formally λ can take on either value yielded by equation (3.10.a). For all practical purposes, this result will typically be a growth rate slightly below that yielded by Fundamental Pair I.2/ This is consistent with the alternative savings hypotheses used in the two cases. It can also be demonstrated that this same condition will, ceteris paribus, cause required exports to be higher in this case than in the profit transfer-GDP saving example above.

Turning to the debt service-GDP saving pair (Fundamental Pair III), with π_1 given, the growth rate is determined by:

$$3.12.a)\ \lambda = k(\alpha + \pi_1)$$

as in the case of Fundamental Pair I and the export ratio by:

$$b)\ \pi_2 = m + \pi_1[\frac{A(r,T)}{k(\alpha + \pi_1)}\{1 - e^{-k(\alpha + \pi_1)T}\} - 1]$$

where A is defined in (2.20.1).

1/ See Appendix I, Paragraph 4.

2/ Typically, the larger growth rate will be somewhat less than $k(\alpha + \pi_1)$, while the lower growth rate will be positive and small. The lower growth rate is apparently not meaningful for a description of an economic system since it is usually small enough to cause the resulting value of π_2 to be greater than one.

The export ratio, π_2, will equal the ratio of imports to gross domestic product if:

$$3.13) \quad \frac{r(1 - e^{-\lambda T})}{\lambda(1 - e^{-rT})} = 1$$

This is true whenever $r = \lambda$. That is, when the interest rate on foreign indebtedness equals the growth rate, the effect of foreign loans on the balance of payments is neutral. If the interest rate exceeds the growth rate ($r > \lambda$), then the effect of foreign saving on the balance of payments is negative; if the growth rate exceeds the interest rate ($\lambda > r$), then the effect is positive. This argument is independent of the length of the repayment period.[1/] However, the magnitude of the effect on the balance of payments when the growth rate does not equal the interest rate ($\lambda \neq r$) does depend on the length of the repayment period.

This conclusion is a strong one since it provides a ready indication of the compatibility of export development, the interest rate on foreign borrowing, and the growth of the economy. The conclusion that the repayment period is irrelevant arises from the fact that we assume the economy is growing regularly. If foreign borrowing were to start in a situation in which it had not taken place before, then during the early years the length of repayment period would effect the repayment burden even though the growth rate equals the interest rate.

1/ See Appendix I, Paragraph 5, for proof.

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The conclusions derived from this exercise, although in some cases suggesting policy implications of considerable importance, are meant to be illustrative of the usefulness of the debt service-capital transfer model. It will be apparent from the exercise, however, that this system provides a new method for gaining insights into neglected aspects of the development problem. The hypothesis that, under certain conditions, there is a meaningful relationship between the profit transfer rate on foreign-owned capital stock and the import-export balance, for example, has profound implications for development planning, particularly in small, open economies. We wish to stress, however, that the eventual usefulness of the model in this regard requires a considerable amount of further theoretical and empirical work.

Work applying the present debt service-profit transfer model to actual planning situations is now underway at NPA's Center for Development Planning. Three studies are to be done: (1) The rules of thumb for this model are to be tested both by computer runs for assumed values and against observed values of the parameters for a large number of countries. Parameter values required by the model are being estimated from the available data. These values will be used to solve the Fundamental Pairs for some parameters, given the others. A similar procedure will be used for published plans to determine if their implicit parameters are consistent with one of the Fundamental Pairs. (2) One or two countries will be selected for an intensive application of the model, using the regular growth solutions presented above. (3) Finally, a policy paper, summarizing policy conclusions from both the theoretical and empirical work, is anticipated.