Fiscal Policy and Economic Growth in Presence of Foreign Aid [The Sri Lankan Experience]

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ABSTRACT

The central debate of this study is regarding the impact of foreign aid on economic growth. In this work we tried to make a link between two stems of aid –growth literature by employing two-step procedure and thereby to capture the net effect of foreign aid on growth transmitted via fiscal policy variables. At first, we estimated fiscal response model by maximizing the welfare function of public policy maker. We employed 3SLS estimation method. Secondly, we estimated the impact of public investment on growth in a room of micro-macro paradox. We used 2SLS estimation procedure. Finally, two models were merged to capture the net effect of foreign aid on growth transmitted via fiscal policy variables. We found that the reliance on foreign aid does not offer better solution for high and rapid growth in prevailing fiscal behavior in Sri Lanka. Finally, some policy and strategic implications were suggested corresponding to the required policy direction of maximizing the productivity enhancement and domestic resource mobilization.

Key words: Fiscal policy; Economic growth; Foreign aid; Public investment; Public consumption; 3SLS; Aid effectiveness;

JEL Codes: E62, H54, O23

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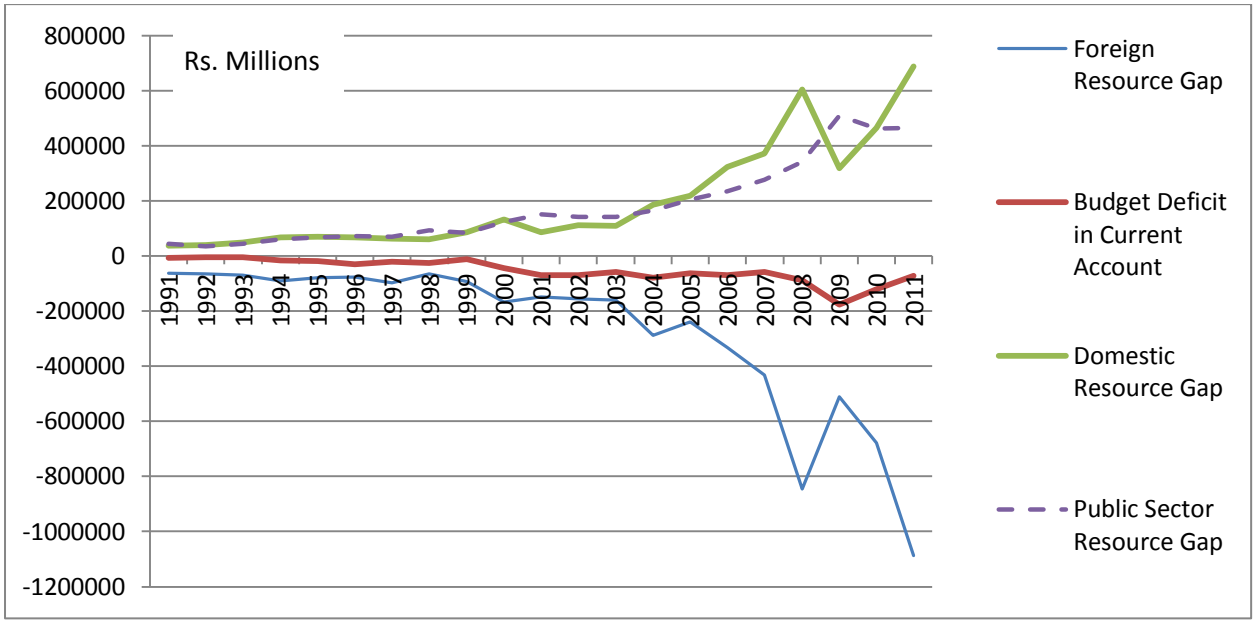
I

INTRODUCTION

Gap model argument and macro-economic challenges

The 'gap model' argument predicts that foreign aid can supplement savings, foreign exchange and public revenue and that it serves to manage the domestic resource gap, the foreign resource gap and fiscal gap, respectively. It should be used not only filling these gaps temporarily, but also for closing the gaps over time, and accelerating and sustaining growth without aid. But its controversial claims are that foreign aid works to create and expand the macro-economic gaps. Figure 1 shows the trends of macro-economic gaps in Sri Lanka. It is clear the country is straying from the path created by gap model predictions and, as a result, the gaps are expanding tremendously instead of closing, even though foreign aid has been poured continuously into the economy throughout the past six decades.

Figure 1: Behavior of Macro Economic Gaps in Sri Lanka



[Source: Central Bank Annual Reports 2012, 2008, 2004, 1999, 1995, Sri Lanka]

Accordingly, this paper attempts to reveal the aid- growth relationship in the prevailing fiscal behavior in Sri Lanka and further it is elaborated in two specific objectives and research questions as bellow.

- To assess the effect of foreign assistance on fiscal policy variables such as public investment, public revenue and government consumption in Sri Lanka.

- To assess the impact of foreign aid on economic growth in Sri Lanka.

Research questions

To achieve the expected objectives, following research questions are analyzed in this research.

1. What is the fraction of taxes which is going to government investment?
2. What is the fraction of foreign aid which is going to government investment?
3. How can the behavior of fiscal variables in presence of foreign aid be explained?
4. What are the impacts of foreign aid transmitted via fiscal variables on economic growth?
5. What policy implications should be employed to remove the bottleneck barrier of under- development?

Outline of the study

The rest of the paper is organized as follows: section II is devoted to discussion of the theoretical background of the aid-growth relationship. Section III discusses the model and research methods used here in detail. Section IV explores the results obtained in this study. Finally, section V sums up the research findings, puts forward our conclusions, and suggests some policy implications.

II

LITERATURE REVIEW

Aid-growth relationship

The traditional Harrod-Domar growth model as well as the Solow growth model stresses physical capital formation as a central driving force of economic growth. This output model depends upon the investment rate and on the productivity of those investments. In broad terms, these models assume that growth is constrained by the availability and productivity of capital. The availability of capital or the level of investment is determined by the level of savings.

If domestic savings are insufficient to finance the investment required to attain the target growth rate, it is described as a savings gap (Rosenstein-Rodan, 1961; Fei & Paauw, 1965). In such a scenario, foreign aid is perceived only as an exogenous net increment to the capital stock of the recipient country. Therefore, aid enables a country to increase investment beyond the limits set by the domestic savings rate. Pronk (2001) argued that economic growth higher than would have been possible given the domestic saving rate would lead to

higher income and production and increase future savings and exports, making aid less necessary to reach a given target in later years. Quoting Kith Griffin (1970), Pronk further shows the controversy of the gap model argument. Aid may simply substitute for domestic savings, resulting in increased consumption. In that case, aid will not result in higher investment and growth, or in higher savings. Aid may, according to Griffin, also retard long-run economic growth in many other ways, for instance by altering the composition of investment with a bias towards activities that are not directly productive or have a long gestation period. Aid may have a bias towards capital intensive technology and a tendency to increase the receiving country's subsequent need for capital. Aid may frustrate the emergence of an indigenous entrepreneurial class or delay institutional reforms, and thus slow down rather than accelerate growth (Pronk, 2001). Pronk further restates Friedman's argument that there is no necessity for aid because "if other conditions for economic development are ripe, capital will be readily available through the market; if not, for instance because of inadequate policies of the government concerned, capital made available would be likely to be wasted" (2001, p. 8). A lack of domestic savings reflects a lack of opportunities, not of income.

Bacha (1990) and Taylor (1990) recognized that some developing country governments simply do not have the revenue raising capacity to cover a desired level of investment. Although the fiscal gap is a subset of the saving gap, it may be a binding constraint if there is some limit on public spending. More precisely, the fiscal gap relates to the capacity utilization which has been found to be a major aspect of the growth in developing countries. Hence the government comes forward to increase the capacity utilization by spending on infrastructure and socio-economic services. Efforts to increase the capacity utilization can be restricted, if public resources for investment and imports (intermediate goods) are insufficient. This fiscal gap could be closed by external resources directed to government budget.

A major criticism is that aid allows recipient government expenditures to be redirected into non-productive activities and reduce the tax effort sharply; and thereby may increase the budget deficit. As a result, over time, government saving is lower than it would have been without aid, rather than closing fiscal gap.

However, the argument is that foreign aid is primarily given to recipient government, the government reshuffles it in the budget and hence, any impact of Aid on macro economy will depend on fiscal behavior. Accordingly, if the recipient government spends foreign assistance on development purposes at the margin, aid works well as expected in the gap model predictions. Otherwise foreign aid does not work well. However, one criticisms of aid-

growth literature is that it fails to recognize explicitly the impact of foreign assistance on growth transmitted via fiscal variables. At this point, the aid-growth literature is divided two stems.

One branch, (Hadjimichael et al. (1995), Durbarry et al. (1998), Burnside and Dollar (1997), Hansen,H and Tarp, F., (2000),) has focused on direct relationship between foreign aid and economic growth and it, by the way, ignore the impact of fiscal behavior in presence of foreign aid. However, the empirical evidence from real-world experiences of foreign aid appears rather more mixed and there is no one-to-one relationship between aid and economic growth. Second stem of aid growth literature comprises with fiscal response paradigm in presence of foreign aid. Fiscal response argument [see Heller (1975), Gang and Khan (1991), Khan and Hoshino (1992), McGillivray (1992), Binh and McGillivray (1993), Mavrotas (2002), Otim (1996)] relies on more formal modeling to identify how aid inflows may result in government behavior that undermines the intended growth effect of aid(McGillivray & Morrissey, 1999). This fiscal response paradigm could be illustrated a bit more rigorously, as follows.

Governments are assumed to have indifference curves, expressing their own revenues plus foreign aid (Pack & Pack, 1993). Suppose that a government spends its total resources on investment goods (I_g) and two consumption goods such as civil consumption (G_c) and socio-economic consumption (G_s). All three goods are normal (non-inferior). The government finances for those goods by means of domestically generated resources. BB' represents the domestically financed allocation choices, and point A represents the preferred resource allocation of the recipient country. Figure 2 illustrates this scenario. In addition to its own resources, the country receives an amount of y_1-y_2 of earmarked foreign aid for the good I_g. For simplicity, it is assumed that there is no impact of aid on the relative price of the two goods. Then post-aid budget constraint is B'C'C and B'C' shows that at least the aid amount has to be spent on I_g. However, suppose that the recipient government does not divert any of its resources away from the I_g while spending the earmarked aid on it. In such a case, the post aid consumption combination, point D, is on a higher indifference curve U_2 and thereby, foreign assistance to I_g, however, increases overall utility in short run.

However, Point D is an inefficient resource allocation combination, which does not satisfy the maximum current utility level of general public. Therefore, we presume that two parties, the donor and the recipient government, don't have identical preferences in case of aid spending. Upon receiving aid, therefore, the recipient government mixes it up with

domestic resources and change the pattern of public spending and pattern of revenue effort in terms of both the level and composition of the government budget.

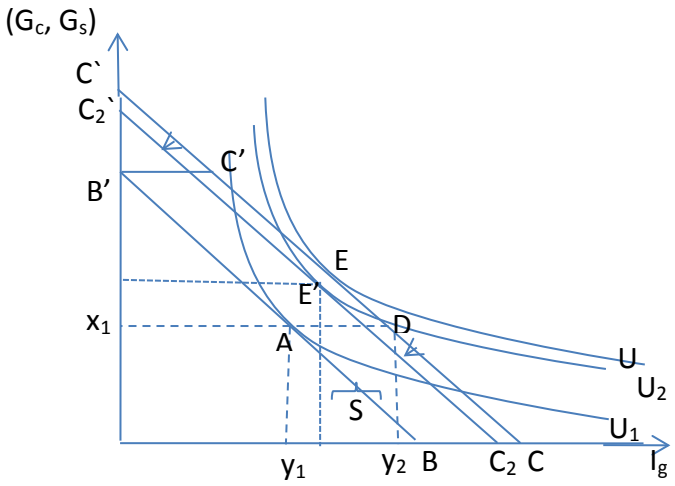


Figure 2. Public Consumption and Revenue Responses in Presence of Foreign Aid

In such situation, while the donor agency would like the aid funds to be spent on I_g at the margin, it is unable to monitor the intended pattern of public spending. If the public policy maker can treat a portion of ($0<s<1$) aid as a resource supplement, then, the government diverts some of its own resources from I_g to G_c and G_s in spending the acquired foreign aid resources on I_g and / or impose a tax reduction policy. Accordingly, the most efficient new resource allocation equilibrium point is given by the point E or E' which are located in higher indifference curves U_2 or U_3. It shows the intention of policy maker to maximize the utility level of the general public in the short run.

The argument is, when the aid funds spend on G_3 at the margin, it leads higher production possibility and much higher utility in future. Aid works well. Otherwise, probably, does not increase the production possibility by the expected amount and it, by the way, does not support reaching to much higher future indifference curve. Aid does not work well. In fiscal response model, however, the impact of aid on growth is widely assumed on the assumption that is categorical aid does not have the desired effect on the targeted projects, either because it is diverted to other public expenditures or to tax reduction. Then only indirect suggestions can be made about how government fiscal behavior affects the aid–growth relationship.

III

METHODOLOGY

As we mentioned earlier, one of the criticisms of the aid-growth literature is that it fails to recognize explicitly that aid is primarily given to a recipient government which then reshuffles it in the budget; thus, any impact of foreign aid on the macro economy will depend on fiscal behavior. Therefore, we suggest a two-step procedure. The first step involves determining the effect of aid on fiscal variables. The second step would involve the estimation of the impact of fiscal variables on growth variables. Then we estimate the net effect of foreign aid on growth transmitted via fiscal policy variables and thereby, we prove the consistency of these two-step models.

Modeling the first step procedure (Fiscal response in presence of foreign aid)

The first step was carried out with a two-dimensional approach: the effect of aid on fiscal variables in terms of source of aid (multilateral vs. bilateral aid) and in terms of type of aid (project loans, non-project loans and grants). In this paper, we followed the model developed by Tran-Nam Binh and McGillivray (1993). [Note: Here we developed the model for case of multilateral vs. bilateral aid and same modeling process followed for the case of different type of aid.]

We assumed that the policy maker has following welfare function (objective function) for any time period *t.*

$$U = f(I_g, G_c, G_s, R, B, A_1, A_2)$$

Where, $I_g$represents public investment expenditure for development purposes; R is for public domestic revenue (tax and non-tax revenues); B for public borrowing from domestic sources; G_c is for government civil expenditure; G_s is for government socio-economic expenditure; A_1 is for bilateral foreign aid and A_2 is for multilateral foreign aid.

Three expenditure categories reflect a functional classification in the budget of Sri Lanka. On the revenue side, in contrast to previous researches, we employed domestic public revenue (R) which includes tax and non-tax revenue, instead of tax revenues (Mavrotas, 2002; Gang & Khan, 1991; Khan & Hoshino, 1991; Phijaisanit, 2010; McGillivray, 2000). All those fiscal variables are viewed as endogenous to the model. Domestic market borrowing is assumed to be a restriction on the policy maker. Multilateral and bilateral foreign aid is viewed as exogenous to the model.

Then, further we assume that the public policy maker is maximizing the following quadratic utility function to get a maximum benefit for the general public.

$$U = \propto_0 - (\frac{\propto_1}{2})(I_g - I_g^*)^2 - (\frac{\propto_2}{2})(R - R^*)^2 - (\frac{\propto_3}{2})(G_c - G_c^*)^2 - (\frac{\propto_4}{2})(G_s - G_s^*)^2 - (\frac{\propto_5}{2})(B - B^*)^2 \quad ①$$

Where the * variables represent the target level of the variables defined above. The meaning of this quadratic loss function is that the policy maker has a predetermined target level of revenue and expenditure side fiscal variables and if there is any deviation from the defined target levels, it is considered as an undesirable loss to the policy maker (Binh & McGillivray, 1993). Then the maximum unconstrained value of U is $\propto_0$, which is obtained when choice variables I_g, G_s, G_c, R and B are set equal to their targets.

To estimate each target variable, we regress each actual variable on some instruments as follows and the fitted values of dependent variables were considered as the planned or targeted variable.

G_c^* $\quad G_c = \rho_0 + \rho_1 G_{c_{t-1}} + \rho_2 R_t^* \quad ②$

I_g^* $\quad I_g = \rho_0 + \rho_1 GDP_{t-1} + \rho_2 I_{g_{t-1}} \quad ③$

G_s^* $\quad G_s = \rho_0 + \rho_1 G_{s_{t-1}} + \rho_2 GDP_{t-1} \quad ④$

$R^* = T^* + nT^* \quad ⑤$

T^* $\quad T = \rho_0 + \rho_1 GDP_{t-1} + \rho_2 IM_t \quad ⑥$

nT^* $\quad nT = \rho_0 + \rho_1 nT_{t-1} + \rho_2 GDP_{t-1} \quad ⑦$

Where, *IM* = Imports, *nT* = Non-Tax revenue, *GDP* = Gross Domestic Product, and rest of the variables are defined the same as above.

Deriving the system of equations in terms of different source of foreign aid

For that, we maximize the above utility function (1) subject to the budget constraints given in equation (8) and (9) which confront the public policy maker. Accordingly, his feasible region of decision mapping is based upon the following institutional constraints.

$$I_g = B + (1 - p_1)R + (1 - p_2)A_1 + (1 - p_3)A_2 \quad ⑧$$

That is, the public investments can be financed partly by domestic public revenues, borrowings, as well as bilateral foreign aid (A_1) and multilateral foreign aid (A_2).

$$G_s + G_c = p_1 R + p_2 A_1 + p_3 A_2 \quad ⑨$$

That is, the public revenue, bilateral and multilateral foreign assistance not used for public investment is directed towards socio-economic and civil administration expenditures.

Where; $(1-p_1)$ = the fraction of public domestic revenues directed to government investment

$(1-p_2)$ = the fraction of bilateral aid directed to government investment

$(1-p_3)$ = the fraction of multilateral aid directed to government investment

Then we form the following Lagrangian by maximizing the utility function (1) of a public policy maker subject to the budget constraints (8) and (9).

$$\text{Max L} = \propto_0 - (\tfrac{\propto_1}{2})(I_g - I_g^*)^2 - (\tfrac{\propto_2}{2})(R - R^*)^2 - (\tfrac{\propto_3}{2})(G_c - G_c^*)^2 - (\tfrac{\propto_4}{2})(G_s - G_s^*)^2 - (\tfrac{\propto_5}{2})(B - B^*)^2 + \lambda_1\{I_g - B - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2\} + \lambda_2\{G_s + G_c - p_1R - p_2A_1 - p_3A_2\} \quad (10)$$

The Lagrangian multiplier yields the following first order conditions (FOC)

$$\partial L/\partial I_g = -\propto_1 (I_g - I_g^*) + \lambda_1 = 0 \quad (11)$$

$$\partial L/\partial G_c = -\propto_3 (G_C - G_C^*) + \lambda_2 = 0 \quad (12)$$

$$\partial L/\partial G_s = -\propto_4 (G_s - G_s^*) + \lambda_2 = 0 \quad (13)$$

$$\partial L/\partial R = -\propto_2 (R - R^*) - \lambda_1(1-p_1) - \lambda_2 p_1 = 0 \quad (14)$$

$$\partial L/\partial B = -\propto_5 (B - B^*) - \lambda_1 = 0 \quad (15)$$

$$\partial L/\partial \lambda_1 = I_g - B - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2 = 0 \quad (16)$$

$$\partial L/\partial \lambda_2 = G_s + G_c - p_1R - p_2A_1 - p_3A_2 = 0 \quad (17)$$

Then by solving the equations (11)-(17), we derived the following set of structural equations: (See the appendix for complete details)

$$G_s = \beta_1 G_s^* - (1-\beta_1)G_C^* + (1-\beta_1)p_1R + (1-\beta_1)p_2A_1 + (1-\beta_1)p_3A_2 \quad (18)$$

$$G_c = (1-\beta_1)G_c^* - \beta_1 G_s^* + \beta_1 p_1 R + \beta_1 p_2 A_1 + \beta_1 p_3 A_2 \quad (19)$$

$$R = \beta_3 p_1 (G_c^* - G_c) + \beta_2 R^* + \beta_4 (1-p_1)\left[I_g - (1-p_2)\boldsymbol{A_1} - (1-p_3)A_2\right] \quad (20)$$

$$I_g = (1-\beta_5)\, I_g^* + \beta_5[(1-p_1)R + (1-p_2)\boldsymbol{A_1} + (1-p_3)A_2] \quad (21)$$

Where,

$\beta_1 = \alpha_4/(\alpha_4+\alpha_3)$

$\beta_2 = \alpha_2/[\alpha_2+\alpha_5\ (1-p_1)^2]$

$\beta_3 = \alpha_3/[\alpha_2+\alpha_5\ (1-p_1)^2]$

$\beta_4 = \alpha_5/[\alpha_2+\alpha_5\ (1-p_1)^2]$

$\beta_5 = \alpha_5/(\alpha_1+\alpha_5)$

Modeling the second step procedure (Fiscal effects on growth variables)

Our major intention with this model is to ascertain the impacts of public investment on economic growth in a room of micro-macro paradox in Sri Lanka. In addition, we incorporate foreign aid and project loans to the same model separately by replacing government investment to explore the direct impact of foreign aid on growth variables. Economic growth and capital formation are embedded in a simultaneous system as an endogenous model. The former equation ㉒ is derived from the Solow growth model and the second ㉓ is the standard type capital formation function.

GR =f (FCFR, APGR,) ㉒

FCFR = f (TPinvR, GR, IgR) ㉓

Where, GR equals the rate of growth of real gross domestic product; FCFR is the percentage of gross fixed capital formation out of GDP; APGR is the growth rate of the active population as a proxy for the labour force; TPinvR is the total private investment (domestic private investment, foreign direct investment and long term private borrowing from foreign sources) as a percentage of GDP; and IgR is the amount of public investment for development purposes as a percentage of GDP.

To this model, we added all policy variables used in the fiscal response model with the purpose of exploring the different aspects of government policy's influences on economic growth and fixed capital formation. However, unlike the capital formation which is based on the stock concept, economic growth is effected by not only the current year but also the previous year's expenditures on government investment and socio-economic expenditure as well as public borrowings. As a result those lag variables were added growth equation and in addition, those lag variables were added to fixed capital formation equation also, with the purpose of eliminating omitted variable bias. Thereby we postulated the following model with two endogenous variables and eleven exogenous variables.

$$GR = \propto_0 + \propto_1 FCFR + \propto_2 APGR + \propto_3 INT + \propto_4 X + \propto_5 X(-1) + \propto_6 G_s R + \propto_7 G_s R(-1) + \propto_8 G_c R + \propto_9 TR + \propto_{10} BR + \propto_{11} BR(-1) + u_t \quad (24)$$

$\propto_1 > 0; \propto_2 > 0; \propto_3 < 0; \propto_4 > 0; \propto_5 > 0; \propto_6 > 0; \propto_7 > 0; \propto_8 < 0; \propto_9 < 0; \propto_{10} < 0; \propto_{11} < 0$

$$FCFR = \propto_{12} + \propto_{13} TPinvR + \propto_{14} GR + \propto_{15} INT + \propto_{16} X + \propto_{17} X(-1) + \propto_{18} G_s R + \propto_{19} G_s R(-1) + \propto_{20} G_c R + \propto_{21} TR + \propto_{22} BR + \propto_{23} BR(-1) + y_t \quad (25)$$

$\propto_{13} > 0; \propto_{14} > 0; \propto_{15} < 0; \propto_{16} > 0; \propto_{17} > 0; \propto_{18} < 0; \propto_{19} < 0; \propto_{20} < 0; \propto_{21} \leqq 0; \propto_{22} \leqq 0; \propto_{23} \leqq 0$

Where, GR is for Growth rate of GDP; FCFR is for Gross fixed capital formation as percentage of GDP; TPinvR is for Total private investment as percentage of GDP; APGR is for Change in active population as a proxy of change in labor force; INT is for Interest rate; GcR is for Public civil expenditure as percentage of GDP; GsR is for Government socio-economic expenditure as percentage of GDP; TR is for Tax revenue as percentage of GDP; BR is for Government Borrowings as percentage of GDP; X is replaced IgR (Public Investment for Development purposes as percentage of GDP), ProLR (Project Loan as percentage of GDP), and AidR (Total Foreign Aid as percentage of GDP) and u & y is for Stochastic error terms.

Subsequently, we derived following reduced form equations for the system of structural equations of the model:

$$GR = \pi_1 + \pi_2 TPinvR + \pi_3 APGR + \pi_4 INT + \pi_5 X + \pi_6 X(-1) + \pi_7 GsR + \pi_8 GsR(-1) + \pi_9 GcR + \pi_{10} TR + \pi_{11} BR + \pi_{12} BR(-1) + \varepsilon_t \quad (26)$$

$$FCFR = \pi_{13} + \pi_{14} TPinvR + \pi_{15} APGR + \pi_{16} INT + \pi_{17} X + \pi_{18} X(-1) + \pi_{19} GsR + \pi_{20} GsR(-1) + \pi_{21} GcR + \pi_{22} TR + \pi_{23} BR + \pi_{24} BR(-1) + \eta_t \quad (27)$$

The model estimation methodology and data sources

In model one, at the first stage, we estimate the target variables by using OLS.In that case, the numbers of specifications were tried for each variable. However, in general, DW statistic is not appropriate to detect the problems of serial correlation in this context given that lagged dependent variables are in the specification. Therefore, comprehensive misspecification tests [the LM test, the heteroscedasticity test, Ramsey's reset test] were

carried out in order to end up with the final parsimonious empirical specifications. The first model at the second stage was estimated by using non-linear 3-stage least squares (3sls) method and the second model was estimated by using 2SLS method. For all estimations, we used E-views statistical software. The first model was estimated twice with required adjustments for different sources of foreign aid and for different types of foreign aid.

This study uses time series data in Sri Lanka for fifty (50) years over the time period 1962-2011 in order to have a more rigorous analysis. The data source is the budgetary statistics of the country supplemented by the *Annual Reports of the Central Bank of Sri Lanka*. All the data have been converted to real terms by deflating the current values using a GDP deflator based on 2002. All data including foreign assistance are reported in local currency-Sri Lankan rupees.

Aid effectiveness under prevailing fiscal behavior

Then we have to consider the consistency of the two models. Therefore, we estimate the net effect of foreign aid on growth transmitted via fiscal policy variables by replacing direct incremental effects of different aid categories on fiscal variables in Model 1on Model 2.

$$\boldsymbol{GR} = \alpha_4 \mathbf{IgR} + \alpha_5 \mathbf{IgR(-1)} + \alpha_6\, \boldsymbol{G_s}\mathbf{R} + \alpha_7\, \boldsymbol{G_s}\mathbf{R(-1)} + \alpha_8\, \boldsymbol{G_c}\mathbf{R} + \alpha_9\, \boldsymbol{TR} + \alpha_{10}\, \boldsymbol{BR} + \alpha_{11}\, \boldsymbol{BR}(-1)$$

$$= (\alpha_4 + \alpha_5)\, \mathbf{IgR} + (\alpha_6 + \alpha_7)\, \boldsymbol{G_s}\mathbf{R} + \alpha_8\, \boldsymbol{G_c}\mathbf{R} + \alpha_9\, \boldsymbol{TR} + (\alpha_{10} + \alpha_{11})\, \mathbf{BR}$$

$$= (\alpha_4 + \alpha_5)\boldsymbol{\beta_5}(\mathbf{1} - \boldsymbol{p_i})\boldsymbol{A_i} + (\alpha_6 + \alpha_7)(\mathbf{1} - \boldsymbol{\beta_1})\boldsymbol{p_i}\boldsymbol{A_i} + \alpha_8\, \boldsymbol{\beta_1}\boldsymbol{p_i}\boldsymbol{A_i} + \alpha_9\, \boldsymbol{\beta_4}(\mathbf{1} - \boldsymbol{p_1})[-(\mathbf{1} - \boldsymbol{p_i})\boldsymbol{A_i}] + (\alpha_{10} + \alpha_{11})\, \mathbf{BR}$$

Direct incremental effect of bilateral aid on G_s and G_c are equal to $(1-\beta_1)p_2$, $\beta_1 p_2$ respectively.

Direct incremental effect of multilateral aid on G_s and G_c are equal to $(1-\beta_1)p_3$, $\beta_1 p_3$

Direct incremental effect of bilateral aid on R is $\beta_4(1-p_1)[-(1-p_2)]$

Direct incremental effect of multilateral aid on R is $\beta_4(1-p_1)[-(1-p_3)]$

Direct incremental effect of bilateral aid on Ig is $\beta_5(1-p_2)$

Direct incremental effect of multilateral aid on Ig is $\beta_5(1-\mathrm{p}_3)$

Limitations

A key challenge faced in this paper, as in previous literature, was derivation of the target variables for model 1. Although the target variables are essential for the succeeding estimation of the model, it is invisible in the real world and has to be approximated as there is no other option. However, the approximation approach is used extensively in the relevant literature. (Mavrotas, 2002; Gang & Khan, 1991; Khan & Hoshino, 1991, Otim, 1996)

Another issue is that we could not find a single model to capture the impact of foreign aid which has been reshuffled into the government budget. Therefore, we had to use two different models and amalgamate them to understand the transitional net impact of foreign aid. Sample data over 50 years are not presented in a consistent manner in the data sources; therefore we made some adjustments which might slightly influence the empirical results.

IV

RESULTS AND INTERPRETATIONS

Estimates of target values

Tables 1 and 2 report the estimation results of target variables and related misspecification tests which are employed in model 1 respectively.

Table 1. Estimates of the Target Values for 1962-2011

Dependent variables	Regresses	Summary Statistics
$\mathbf{I}_g$	7663168605.3 + 0.014 GDP_{t-1}** + 0.73 $I_{g_{t-1}}$*** [1.20] [2.27] [7.31]	R^2 - 0.761 DW - 2.217
$\mathbf{G}_c$	- 8413733917.1 + 0.654$G_{c_{t-1}}$*** + 0.295(R*)*** [-1.71] [6.03] [3.32]	R^2 - 0.980 DW - 2.25
$\mathbf{G}_s$	11651430650.6 + 0.640$G_{s_{t-1}}$*** + 0.023 GDP_{t-1}*** [2.62] [5.18] [3.04]	R^2 - 0.952 DW - 1.638
T	37062398741 + 0.087GDP_{t-1}*** + 11.13 IM*** [8.68] [6.99] [3.49]	R^2 - 0.967 DW - 0.72
nT	2750000000 + 0.561nT_{t-1}*** + 0.008GDP_{t-1}*** [1.91] [4.76] [3.74]	R^2 - 0.866720 DW - 2.124346

Note: t-ratios are reported in square brackets below the coefficients.

According to the estimation results, all coefficients of predetermined variables of each equation are positive and statistically significant. All the specifications are relatively good in the light of the reported R^2s. Results of the diagnostic tests suggest that there is a serial correlation and functional form misspecifications in **T**. Hence, to fix the problem, we regressed the equation for correcting serial correlation and obtained the results in table 3. However, an interesting point in the estimation is that the above specification for the target variables (G_s^*, $\mathrm{I}_g^*, \mathrm{G}_c^*, T^*, \mathrm{n}T^*$) gently fits with the related values of budgetary variables in Sri Lanka.

Table 2. Estimation Results of Misspecification Diagnostic Tests

	Heteroscedasticity test	LM Test	Ramsey's RESET Test
$\mathbf{I_g}$	$\chi^2(5)$: 11.38 [0.04] F(5,43) : 2.60 [0.03]	$\chi^2(1)$: 1.08 [0.29] F(1,45) : 1.01 [0.31]	$\chi^2(1)$: 3.49 [0.06] F(1,45) : 3.32 [0.07]
$\mathbf{G_C}$	$\chi^2(5)$: 6.41 [0.26] F(5,42) : 1.29 [0.28]	$\chi^2(1)$: 2.39 [0.12] F(1,44) : 2.31 [0.13]	$\chi^2(1)$: 3.98 [0.04] F(1,44) : 3.81 [0.05]
$\mathbf{G_s}$	$\chi^2(5)$: 3.68 [0.59] F(5,43) : 0.69 [0.62]	$\chi^2(1)$: 4.72 [0.03] F(1,45) : 4.79 [0.03]	$\chi^2(1)$: 0.08 [0.77] F(1,45) : 0.07 [0.70]
T	$\chi^2(5)$: 9.39 [0.09] F(5,43) : 2.03 [0.09]	$\chi^2(1)$: 19.79 [0.00] F(1,45) : 30.49 [0.00]	$\chi^2(1)$: 10.87 [0.00] F(1,46) : 11.18 [0.00]
nT	$\chi^2(5)$: 11.31 [0.04] F(5,43) : 2.58 [0.04]	$\chi^2(1)$: 0.89 [0.36] F(1,45) : 0.83 [0.34]	$\chi^2(1)$: 2.93 [0.08] F(1,45) : 2.77 [0.10]

Table 3. Correcting serial correlation

Dependent variables	Regresses	Summary Statistics
T	**37777112531 $+0.099\ \mathbf{GDP_{t-1}}$ ***+7.13 IM***+0.66 (AR1)** **[3.77]** **[7.11]** [2.2] [5.63]	**R^2 - 0.98** **DW - 1.77**

[*Note: t*-ratios in square brackets below the coefficients.]

Fiscal responses in presence of foreign aid

This section turns the discussion towards the empirical findings of the responses of four endogenous variables, I_g, G_c, G_s and R, to any changes in the level and form of foreign assistance. Estimated results in case of foreign aid source and type of foreign aid are shown in table 4 and 5 respectively.

The revenue parameters are the curial budget constraint parameters which respectively show the consumption responses to an increase in domestic public revenue, and any form of foreign assistance. Accordingly, $\boldsymbol{p_1}$ is positive and statistically significant at the 1% level by suggesting that when revenue effort increases by 1%, then the consumption increases by around 1.3%. Hence, there is considerable tendency to pull funds out of development projects to supplement non development expenditure. It is important to note that the Sri Lankan government might finance public investment projects from the domestic public revenues if foreign aid were not received. Our result of the coefficient associated with $\boldsymbol{p_1}$ is in sharp contrast to the one obtained by Otim (1996), through a different approach. He reports a negative coefficient for $\boldsymbol{p_1}$ by using panel data for India, Pakistan and Sri Lanka over the period of 1977-1990. Khan and Hoshino (1992) suggest that 88% of the taxes flow to

consumption in the presence of foreign aid by using pooled time series and cross sectional data over the time period of 1955-1976 of five countries including Sri Lanka.

Table 4. Estimation Results of Fiscal Impacts of Multilateral and Bilateral Foreign Aid

Estimation Method: Three-Stage Least Squares; Sample: 1963- 2011; Included observations: 49			
Total system (unbalanced) observations 193; 20 total coefficient iterations			
Parameter	**Coefficient**	**Std. Error**	***t*-Statistic**
p_1	1.311	0.052	24.98
p_2	-0.466	0.224	-2.080
p_3	-1.115	0.585	-1.70
β_1	0.515	0.050	10.20
β_2	1.011	0.016	59.89
β_3	-0.720	0.184	-3.89
β_4	0.731	0.432	1.69
β_5	0.010	0.038	0.27

Table 5. Estimation Results of Project Loan, Non-project Loan and Grant Aid

Estimation Method: Three-Stage Least Squares; Sample: 1963- 2011 Included observations: 49			
Total system (unbalanced) observations 193 24 total coefficient iteration			
Parameters	**Coefficient**	**Std. Error**	**t-Statistic**
p_1	1.291	0.053	23.99
p_2	-0.644	0.378	-1.70
p_3	-0.218	0.219	-0.99
p_4	-0.544	0.464	-1.17
β_1	0.510	0.049	10.37
β_2	1.015	0.017	57.97
β_3	-0.712	0.176	-4.02
β_4	0.892	0.397	2.24
β_5	0.006	0.039	0.16

The most interesting finding, however, is that the income elasticity with respect to bilateral aid (p_2) is considerably less than the multilateral aid (p_3). Three explanations seem most reasonable: Multilateral aid is more conditional than bilateral assistance; multilateral aid is tending to be financed large-scale projects/programs and, as a result the requirement of counterpart domestic resources is higher; the development component of multilateral assistance is higher than that of bilateral assistance.

On the other hand, the income elasticity with respect to bilateral assistances,(p_2), multilateral (p_3) and project loan (p_4) can be said to be negative and far from zero by implying that

when increase such foreign assistance, there is tendency to decrease the public consumption. Further $\boldsymbol{p_4}$ suggest that development projects are competing with government consumption for domestic resources and there is tendency to pull funds out of non-investment expenditures.

Public revenue, bilateral and multilateral parameters together indicate that tax and non-tax revenue are used for current expenses of running the government and foreign assistance is needed for implementing the development plan in circumstances of domestic borrowings.

Estimated $\boldsymbol{\beta}$ parameters in the model show some fiscal responses in the Sri Lankan scenario.

- $\boldsymbol{\beta_1}$ reflects the relationship between socio-economic consumption ($\boldsymbol{G_s}$) and targeted expenditures of government consumption as well as the receiving side of the budget. For targeted expenditure, a positive coefficient, 0.51, is statistically significant at the 1% level and suggests that by setting higher targeted $\boldsymbol{G_s}$, government authorities end up with allocating funds equally to $\boldsymbol{G_s}$ and $\boldsymbol{G_c}$ and vice versa. It means $\boldsymbol{G_s}$ and $\boldsymbol{G_c}$ closely interacts with each other.
- On the receiving side, $\boldsymbol{\beta_1}$ indicates what proportion of foreign aid and taxes go to $\boldsymbol{G_c}$ as opposed to $\boldsymbol{G_s}$. Accordingly, around 49% of public revenue which is directed to consumption goes to socio-economic expenditure and the rest goes to civil consumption expenditure. Similarly, around 49% of foreign aid (bilateral aid, multilateral aid and project loan) which tends to pull funds from consumption is from socio-economic expenditures and rest is from civil consumption expenditure.
- β_2 reflects the relationship between targeted and actual revenues. The coefficient $\boldsymbol{\beta_2}$ is positive and statistically significant at the 1 percent level and close to 1 in this case. It suggests that, higher targeted revenues are related very closely to higher actual revenues. In comparison, Otim (1996) reports an estimation result instead of β_2 far from 1 by using panel data for India, Pakistan and Sri Lanka over the period of 1977-1990.
- $\boldsymbol{\beta_3}$ indicates the revenue effort to targeted and actual expenditures. Negative $\boldsymbol{\beta_3}$, is statistically significant at the 1 percent level and suggests that the government authority intends to reduce the tax effort in a situation of $G_c^* > G_c$.
- Even if $\boldsymbol{\beta_4}$ is positive and statistically significant, according to the $\boldsymbol{p_1}$, the revenue effort is increased in the presence of foreign assistance. On the other hand, $\boldsymbol{p_1}\,\boldsymbol{\beta_3}$, and inverse $\boldsymbol{p_1}$ and $\boldsymbol{\beta_4}$ together implies that the domestic revenue decision is more heavily

influenced by the need of civil consumption considerations than by the need of investment considerations.

As a whole, regarding the overall fit of the estimated simultaneous equations models, the results were obtained without very serious computational problems and convergence was achieved with 20 iterations in the estimation of the model we used for different sources of foreign aid and with 24 iterations in the estimation of the model we used for different type of foreign aid.

Aid-growth relationship

Now we turn the analysis toward the impact of foreign aid on growth transmitted via fiscal variables. Firstly we estimated the impact of government investment on growth variables. In addition, we incorporate foreign aid and project loans into the same model for further clarification. (See table 6). Subsequently, we merged the estimation results of model 1 and 2 as explained above and thereby, we elaborate the net effect of foreign aid on growth transmitted via fiscal policy variables (See table 7).

With public investment, we can observe that it does not have any impact on economic growth in the long run. Similarly, net impact of foreign aid on growth transmitted via government investment is also zero by suggesting that, [Paul Mosley et al. (1987), Sri Lanka be categorized as a "high aid, low growth country" (p. 623).] Economic growth is influenced by the fiscal policy effects as well as by project implementation and operational issues. White (1992, p.164) notes that aid always tends to raise the growth rate during the period of aid but in the long term it depends on recipient countries' ability to mobilize their own resources. As confirmed by the results of the fiscal response model, over time, government saving is lower than it would have been without aid (Foreign aid does not support the closing of fiscal gaps). Thereby, in contrast to the gap model prediction, aid does not supplement domestic savings, hence it does not increase investment and, from a long term perspective, it may cause a decline in the recipient countries' ability to mobilize their own resources and thereby has no impact on growth. In addition, some backwash effects, such as crowds out private investment and private activities, lead to no impact on economic growth as suggested by the empirical findings of public borrowing in this case.

In addition to the policy effects, some other project implementation and operational issues cause the phenomenon of aid resulting in having no impact. As is often the case, government investment finances largely unnecessary investment activities that tend to generate low or negative rates of return and produce little spillovers into other sectors. Paul Mosley et al.

(1987) mention that "the general finding is that the rate of return on capital is higher and the share of aid inflows allocated to the development budget are, on average, higher in 'high aid, high growth' countries than in 'high aid, low growth' countries". In addition, adequate maintenance of the infrastructure might not be occurred in regularly due to domestic resources are completely directed to the public consumption as pointed out in the results of the fiscal response model.

Table 6. 2SLS Parameter Estimate of Aid - Growth Relationship (1962-2011)

Variable	Expected sign		GR	FCFR	GR	FCFR	GR	FCFR
	GR	FCFR						
C			-0.34	0.39	2.40	1.16	-1.82	-0.46
FCFR	+		0.33**		0.38***		0.36***	
GR		+		0.01		0.45		1.25
APGR	+		0.69^{M}		0.34		0.37	
TPinvR		+		0.57***		0.52**		0.29
INT	-	-	0.26*	0.02	0.26*	-0.18	0.21^{M}	-0.21
IgR	+	+	0.22*	0.4*				
IgR(-1)	+	+	-0.22**	0.16^{M}				
AidR	+	+			0.35*	0.58		
AidR(-1)	+	+			-0.37*	0.23		
ProLR	+	+					0.21	-0.6
ProLR(-1)	+	+					-0.49^{M}	0.68
GsR	+	-	0.34^{M}	-0.35^{M}	0.15	-0.62***	0.18	-0.32^{M}
GsR (-1)	+	-	0.06	-0.18	0.30	-0.13	0.13	0.23
GcR	-	-	-0.33^{M}	0.21	-0.38^{M}	-0.01	-0.25	-0.56^{M}
TR	-	+/-	-0.21	0.58**	-0.10	0.72**	-0.05	0.34
BR	-	+/-	-0.27*	0.37**	-0.29*	0.72***	-0.32^{M}	0.58***
BR(-1)	-	+/-	-0.40**	0.15	-0.36**	0.35^{M}	-0.34**	0.6*
R^2			0.51	0.91	0.53	95.17	0.51	0.91
DW			1.78	1.91	2.31	1.51	1.78	1.91

Note: ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level; M – Significant at 20% level

Similarly, economic growth is badly affected by public investment when financed by a foreign aid inflow which causes a much higher foreign resource outflow. Generally speaking, most of the foreign assistance discourages handling the operations of project by the recipient government agencies or at least the domestic private sector agencies by strongly imposing open international bidding conditions. Therefore, the foreign aid assistance does not remain in the recipient economy and foreign aid leakage hugely exceeds the inflow of such foreign assistance.

Table 7. Net Effect of Foreign Aid on Growth Transmitted via Fiscal Policy Variables

Direct incremental effect			**GR**	
	IgR		**0**	
Bilateral aid	$\beta_5(1-p_2)$	0	0	Net effect of aid on growth transmitted via IgR
Multilateral aid	$\beta_5[(1-p_3)]$	0	0	
Project loan aid	$\beta_5[(1-p_4)]$	0	0	
	Gs		0.34	
Bilateral aid	p_2 (1 - β_1)	-0.226	-0.07	Net effect of aid on growth transmitted via Gs
Multilateral aid	p_3 (1 - β_1)	-0.54	-0.18	
Project loan aid	p_4 (1 - β_1)	-0.31	-0.10	
	Gc		-0.33	
Bilateral aid	p_2 β_1	-0.239	0.07	Net effect of aid on growth transmitted via Gc
Multilateral aid	p_3 β_1	-0.574	0.19	
Project loan aid	p_4 β_1	-0.328	0.10	
	R		0	
Bilateral aid	$\beta_4(1-p_1)$[-1(1 − p_2)]	0.33	0	Net effect of aid on growth transmitted via R
Multilateral aid	$\beta_4(1-p_1)$[-1(1 − p_3)]	0.47	0	
Project loan aid	$\beta_4(1-p_1)$[-1(1 − p_4)]	0.42	0	
	BR		-0.67	
			-0.67	Overall fiscal effect on economic growth

The direct effect of socio-economic expenditures on growth is positive and significant at the 20% level while it crowds out the government investment. But the net effect of aid on growth transmitted via ***Gs*** is negative in the long run by suggesting that foreign aid crowd out

socio-economic consumption. Direct effect of civil expenditures on growth is negative and significant at 20 % level while it crowd out the government investment. But net effect of aid on growth transmitted via ***Gc*** is positive in the short run by suggesting that foreign aid crowds out public civil consumption and it makes better results for economic growth.

However, according to Table 6, we can see that the overall fiscal effect on economic growth in the presence of foreign aid is negative due to rapid increases in domestic borrowings.

V

CONCLUSIONS AND RECOMMENDATIONS

The debate of this thesis centers on the impact of foreign aid on economic growth. The predictions of the gap model argue that foreign aid should play a role in closing gaps over time, rather than merely filling gaps, and thereby contribute to higher economic growth through domestic resource mobilization. But, one criticisms of the aid-growth literature is that it fails to recognize clearly that any impact of foreign aid on the macro economy depends on fiscal behavior. Therefore, we employed a two -step procedure to capture the effect of foreign assistance on fiscal policy variables and secondly to capture the impact of policy variables on economic growth. Subsequently, we estimated the net effect of foreign aid on growth transmitted via fiscal policy variables by establishing the consistency of the two models. We used a simultaneous equation model derived by maximizing the welfare function of public policy maker subject to given budget constraints, including foreign assistance. The second step used a simultaneous two -equation endogenous model consisting of a growth equation accompanied by a Solow growth paradigm and a standard capital formation equation and hanged all fiscal policy variables used in the first step. Time series data from 1962- 2011 for Sri Lanka was used for estimations. Estimation results for the first model were derived by running three-stage least square method. The second step followed the two -stage least square method.

The fact that revenue parameters were found, separately, in both estimations implies that domestic public revenue is used for current expenses of running the government and foreign assistance is needed to implement the development plan in the circumstance of domestic borrowings. In addition, the results indicate that foreign aid allows an increase in public revenue, which in turn, allows the government to increase consumption more rapidly. As a result, government savings are lower than it would have been without aid. Further, it suggests

that a public policy maker has relatively given a higher priority to strengthening the government institutional setting rather than to development priorities. In the second step of this research, we found that the net effect of foreign aid on growth transmitted via the government investment channel does not have any impact on economic growth by suggesting that foreign aid does not work properly on the growth strategy. In addition, we can conclude that overall impact of foreign aid via fiscal behavior on economic growth is unfavorable due to rapid increases in domestic borrowings. It means growth is negatively influenced by the backwash effects of fiscal policy as well as by project implementation and operational issues. Aid does not supplement domestic savings, neither does it increase investment. From a long term perspective, it causes a decline in the recipient countries' ability to mobilize their own resources and thereby has no impact on economic growth. The ultimate conclusion is that the reliance on foreign aid does not offer a better solution for high and rapid growth under the prevailing fiscal behavior. It further proves that it bring the economy from bad to worst. In this scenario, as a whole, the suggested policy direction is to direct the maximum effort towards productivity enhancement and domestic resource mobilization. Accordingly, the government should achieve the benchmark of $P1 \leq 1$; tighten policy for domestic borrowings; make structural adjustments to ensure $Gs > Gc$ considerably; create effective policy to minimize foreign aid leakages; promote government investment policy to encourage the productivity and accountability of foreign aid and non-governmental strategies to provide public investment goods. In addition, some strategic implications such as strengthening the planning and budget monitoring, promoting the CECB as a development leader, and introducing management audits for development projects are also suggested.

Contribution to the literature

In this work we tried to make a link between two stems of aid –growth literature by employing two-step procedure in aid growth nexus and thereby to capture the net effect of foreign aid on growth transmitted via fiscal policy variables. According to my references, I found that previous researches had carried out one of two steps and due to this reason, those researches are not appropriate to discuss the aid-growth relationship. Much research (Hadjimichael et al. (1995), Durbarry et al. (1998), Burnside and Dollar (1997), Hansen,H and Tarp, F., (2000),) has focused on direct relationship between foreign aid and economic growth and it, by the way, ignore the impact of fiscal behavior in presence of foreign aid. Some earlier works in fiscal response argument [see Heller (1975), Gang and Khan (1991), Khan and Hoshino (1992), McGillivray (1992), Binh and McGillivray (1993), Mavrotas

(2002), Otim (1996)] had tried to see the impact of foreign aid on fiscal variables. Then only indirect suggestions can be made about how government fiscal behavior affects the aid–growth relationship as it is widely assumed that categorical aid does not have the desired effect on the targeted projects, either because it is diverted to other public expenditures or to tax reduction..

One difficulty with earlier works in fiscal response paradigm [see Heller (1975), Gang and Khan (1991), Khan and Hoshino (1992), McGillivray (1992), Binh and McGillivray (1993), Mavrotas (2002), Otim (1996)] is that the data used are a pooled cross-section of different countries with a few time series observations or an inadequacy of time-series data set for a single country. Whatever the strategy, to draw empirically valid conclusion about a single country from such data is hazardous. But this research has used consistent time series data over a period of 50 year for single country (Sri Lanka) case and the estimation results are comparatively more acceptable.

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Appendix 1

In this appendix, we show the derivative process of fiscal response model we used in the chapter 3 in details.

We assume that the public policy maker is maximizing the following quadratic utility function to get a maximum benefit for the general public.

$$U = \propto_0 - (\tfrac{\propto_1}{2})(I_g - I_g^*)^2 - (\tfrac{\propto_2}{2})(R - R^*)^2 - (\tfrac{\propto_3}{2})(G_c - G_c^*)^2 - (\tfrac{\propto_4}{2})(G_s - G_s^*)^2 - (\tfrac{\propto_5}{2})(B - B^*)^2 \quad ①$$

Where, $I_g$represents public investment expenditure for development purposes; R is for public domestic revenue (tax and non-tax revenues); B for public borrowing from domestic sources; G_c is for government civil expenditure; G_s is for government socio-economic expenditure; A_1 is for bilateral foreign aid and A_2 is for multilateral foreign aid; $\propto \geq 0$; the '*' represent the target level for each variable we have just defined.

We maximize the above utility function (1) subject to the budget constraints given in equation (2) and (3) which confront the public policy maker. Accordingly, his feasible region of decision mapping is based upon the following institutional constraints.

$$I_g = B + (1 - p_1)R + (1 - p_2)A_1 + (1 - p_3)A_2 \qquad (2)$$

$$G_s + G_c = p_1R + p_2A_1 + p_3A_2 \qquad (3)$$

Where; $(1 - p_1)$ = the fraction of public domestic revenues directed to government investme

$(1 - p_2)$ = the fraction of bilateral aid directed to government investment

$(1 - p_3)$ = the fraction of multilateral aid directed to government investment

Then we form the following Lagrangian by maximizing the utility function (1) of a public policy maker subject to the budget constraints (2) and (3).

$$\text{Max L} = \propto_0 - (\tfrac{\propto_1}{2})(I_g - I_g^*)^2 - (\tfrac{\propto_2}{2})(R - R^*)^2 - (\tfrac{\propto_3}{2})(G_c - G_c^*)^2 - (\tfrac{\propto_4}{2})(G_s - G_s^*)^2 - (\tfrac{\propto_5}{2})(B - B^*)^2 + \lambda_1\{I_g - B - (1 - p_1)R - (1 - p_2)A_1 - (1 - p_3)A_2\} + \lambda_2\{G_s + G_c - p_1R - p_2A_1 - p_3A_2\} \qquad (4)$$

The Lagrangian multiplier yields the following first order conditions (FOC)

$$\partial L/\partial I_g = -\propto_1 (I_g - I_g^*) + \lambda_1 = 0 \qquad (5)$$

$$\partial L/\partial G_c = -\propto_3 (G_C - G_C^*) + \lambda_2 = 0 \qquad (6)$$

$$\partial L/_{\partial G_s} = -\propto_4 (G_s - G_s^*) + \lambda_2 = 0 \quad (7)$$

$$\partial L/_{\partial R} = -\propto_2 (R - R^*) - \lambda_1(1 - p_1) - \lambda_2 p_1 = 0 \quad (8)$$

$$\partial L/_{\partial B} = -\propto_5 (B - B^*) - \lambda_1 = 0 \quad (9)$$

$$\partial L/_{\partial \lambda_1} = I_g - B - (1 - p_1)R - (1 - p_2)A_1 - (1 - p_3)A_2 = 0 \quad (10)$$

$$\partial L/_{\partial \lambda_2} = G_s + G_c - p_1 R - p_2 A_1 - p_3 A_2 = 0 \quad (11)$$

Then by solving the equations (5)-(11), we derived the following set of structural equations:

The derivation of $\boldsymbol{G_s}$

From (7) we get,

$$-\propto_4 (\boldsymbol{G_s} - \boldsymbol{G_s^*}) + \boldsymbol{\lambda_2} = \boldsymbol{0}$$

$$-\propto_4 \boldsymbol{G_s} + \propto_4 \boldsymbol{G_s^*} + \boldsymbol{\lambda_2} = \boldsymbol{0}$$

$$\propto_4 \boldsymbol{G_s} = \propto_4 \boldsymbol{G_s^*} + \boldsymbol{\lambda_2}$$

Then, λ_2 can be derived from (6)

$$-\propto_3 (\boldsymbol{G_C} - \boldsymbol{G_C^*}) + \boldsymbol{\lambda_2} = \boldsymbol{0}$$

$$\boldsymbol{\lambda_2} = \propto_3 (\boldsymbol{G_C} - \boldsymbol{G_C^*})$$

We get Gc from equation (11)

$$G_s + G_c - p_1 R - p_2 A_1 - p_3 A_2 = 0$$

$$G_c = p_1 R + p_2 A_1 + p_3 A_2 - G_s$$

Substituting back to the previous equation we obtain,

$$\propto_4 \boldsymbol{G_s} = \propto_4 \boldsymbol{G_s^*} + \boldsymbol{\lambda_2}$$

$$\propto_4 \boldsymbol{G_s} = \propto_4 \boldsymbol{G_s^*} + \propto_3 (\boldsymbol{G_C} - \boldsymbol{G_C^*})$$

$$\propto_4 \boldsymbol{G_s} = \propto_4 \boldsymbol{G_s^*} + \propto_3 (\boldsymbol{p_1 R} + \boldsymbol{p_2 A_1} + \boldsymbol{p_3 A_2} - \boldsymbol{G_s}) - \propto_3 \boldsymbol{G_C^*}$$

$$\propto_4 \boldsymbol{G_s} = \propto_4 \boldsymbol{G_s^*} + \propto_3 (\boldsymbol{p_1 R} + \boldsymbol{p_2 A_1} + \boldsymbol{p_3 A_2}) - \propto_3 \boldsymbol{G_s} - \propto_3 \boldsymbol{G_C^*}$$

$$\propto_4 \boldsymbol{G_s} + \propto_3 \boldsymbol{G_s} = \propto_4 \boldsymbol{G_s^*} + \propto_3 (\boldsymbol{p_1 R} + \boldsymbol{p_2 A_1} + \boldsymbol{p_3 A_2}) - \propto_3 \boldsymbol{G_C^*}$$

$$\boldsymbol{G_s} = \frac{\propto_4}{\propto_4 + \propto_3} \boldsymbol{G_s^*} - \frac{1 - \propto_4}{\propto_4 + \propto_3} \boldsymbol{G_C^*} + \frac{1 - \propto_4}{\propto_4 + \propto_3} \boldsymbol{p_1 R} + \frac{1 - \propto_4}{\propto_4 + \propto_3} \boldsymbol{p_2 A_1} + \frac{1 - \propto_4}{\propto_4 + \propto_3} \boldsymbol{p_3 A_2} \quad \textbf{(12)}$$

The derivation of $\boldsymbol{G_c}$

From (6) we get,

$$-\propto_3 (\boldsymbol{G_c} - \boldsymbol{G_c^*}) + \boldsymbol{\lambda_2} = \boldsymbol{0}$$

$$-\propto_3 \boldsymbol{G_c} + \propto_3 \boldsymbol{G_c^*} + \boldsymbol{\lambda_2} = \boldsymbol{0}$$

$$\propto_3 \boldsymbol{G_c} = \propto_3 \boldsymbol{G_c^*} + \boldsymbol{\lambda_2}$$

λ_2 can be derived from (7)

$$-\propto_4 (\boldsymbol{G_s} - \boldsymbol{G_s^*}) + \boldsymbol{\lambda_2} = \boldsymbol{0}$$

$$\boldsymbol{\lambda_2} = \propto_4 (\boldsymbol{G_s} - \boldsymbol{G_s^*})$$

We get Gs from equation (11)

$$G_s = p_1 R + p_2 A_1 + p_3 A_2 - G_c$$

Substituting back to the previous equation we obtain,

$$\propto_3 \boldsymbol{G_c} = \propto_3 \boldsymbol{G_c^*} + \boldsymbol{\lambda_2}$$

$$\propto_3 \boldsymbol{G_c} = \propto_3 \boldsymbol{G_c^*} + \propto_4 (\boldsymbol{G_s} - \boldsymbol{G_s^*})$$

$$\propto_3 \boldsymbol{G_c} = \propto_3 \boldsymbol{G_c^*} + \propto_4 (\boldsymbol{p_1 R} + \boldsymbol{p_2 A_1} + \boldsymbol{p_3 A_2} - \boldsymbol{G_c}) - \propto_4 \boldsymbol{G_s^*}$$

$$\propto_3 \boldsymbol{G_c} = \propto_3 \boldsymbol{G_c^*} + \propto_4 (\boldsymbol{p_1 R} + \boldsymbol{p_2 A_1} + \boldsymbol{p_3 A_2}) - \propto_4 \boldsymbol{G_c} - \propto_4 \boldsymbol{G_s^*}$$

$$\propto_3 \boldsymbol{G_c} + \propto_4 \boldsymbol{G_c} = \propto_3 \boldsymbol{G_c^*} + \propto_4 (\boldsymbol{p_1 R} + \boldsymbol{p_2 A_1} + \boldsymbol{p_3 A_2}) - \propto_4 \boldsymbol{G_s^*}$$

$$\boldsymbol{G_c} = \frac{\boldsymbol{1-\propto_4}}{\propto_4 + \propto_3} \boldsymbol{G_c^*} - \frac{\propto_4}{\propto_4 + \propto_3} \boldsymbol{G_s^*} + \frac{\propto_4}{\propto_4 + \propto_3} \boldsymbol{p_1 R} + \frac{\propto_4}{\propto_4 + \propto_3} \boldsymbol{p_2 A_1} + \frac{\propto_4}{\propto_4 + \propto_3} \boldsymbol{p_3 A_2} \qquad \textbf{(13)}$$

The derivation of R

From (8) we get,

$$-\propto_2 (R - R^*) - \lambda_1 (1 - p_1) - \lambda_2 p_1 = 0$$

λ_2 can be derived from (6)

$$\lambda_2 = \propto_3 (G_c - G_c^*)$$

λ_1 can be derived from (9) *under the assumption of* $B^* = 0$,

$$-\propto_5 (B - B^*) - \lambda_1 = 0$$

$$\lambda_1 = -\propto_5 B$$

B can be derived from (10)

$$I_g - B - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2 = 0$$

$$B = I_g - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2$$

Then re-write the equation 8;

$$-\propto_2 (R - R^*) - \{-\propto_5 [I_g - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2]\}(1-p_1) - \propto_3 (G_c - G_c^*)p_1 = 0$$

$$-\propto_2 R + \propto_2 R^* - \propto_5 (1-p_1)^2 R + \propto_5 [I_g - (1-p_2)A_1 - (1-p_3)A_2](1-p_1)] - p_1[\propto_3 (G_c - G_c^*)] = 0$$

$$\propto_2 R + \propto_5 (1-p_1)^2 R = \propto_2 R^* + \propto_5 \left[I_g - (1-p_2) - (1-p_3)A_2\right](1-p_1) + \propto_3 p_1 (G_c^* - G_c)$$

$$\boldsymbol{R = \frac{\propto_3 p_1 (G_c^* - G_c)}{\propto_2 + \propto_5 (1-p_1)^2} + \frac{\propto_2 R^*}{\propto_2 + \propto_5 (1-p_1)^2} + \frac{\propto_5 (1-p_1)[I_g - (1-p_2)A_1 - (1-p_3)A_2]}{\propto_2 + \propto_5 (1-p_1)^2}} \quad \textbf{(14)}$$

The derivation of $\boldsymbol{I_g}$

From (5) we get,

$$-\propto_1 \left(I_g - I_g^*\right) + \lambda_1 = 0$$

$$\propto_1 I_g = \propto_1 I_g^* + \lambda_1$$

λ_1 can be derived from (9) under the assumption of B* = 0:

$$\lambda_1 = -\propto_5 B$$

B can be derived from (10)

$$I_g - B - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2 = 0$$

$$B = I_g - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2$$

Substituting back to the equation (5) and *Then re-write;*

$$\propto_1 I_g = \propto_1 I_g^* - \propto_5 [I_g - (1-p_1)R - (1-p_2)A_1 - (1-p_3)A_2]$$

$$\propto_1 I_g = \propto_1 I_g^* - \propto_5 I_g + \propto_5 [(1-p_1)R + (1-p_2)A_1 + (1-p_3)A_2]$$

$$\propto_1 I_g + \propto_5 I_g = \propto_1 I_g^* + \propto_5 [(1-p_1)R + (1-p_2)A_1 + (1-p_3)A_2]$$

$$\boldsymbol{I_g = 1 - \frac{\propto_5}{\propto_1 + \propto_5} I_g^* + \frac{\propto_5}{\propto_1 + \propto_5} [(1-p_1)R + (1-p_2)A_1 + (1-p_3)A_2]} \quad \textbf{(15)}$$

By letting,

$\beta_1 = \alpha_4/(\alpha_4+\alpha_3)$

$\beta_2 = \alpha_2/[\alpha_2+\alpha_5\ (1-p_1)^2]$

$\beta_3 = \alpha_3/[\alpha_2+\alpha_5\ (1-p_1)^2]$

$\beta_4 = \alpha_5/[\alpha_2+\alpha_5\ (1-p_1)^2]$

$\beta_5 = \alpha_5/(\alpha_1+\alpha_5)$

We simplified the above structural equations as follows

$$G_s = \beta_1 G_s^* - (1-\beta_1)G_C^* + (1-\beta_1)p_1 R + (1-\beta_1)p_2 A_1 + (1-\beta_1)p_3 A_2 \quad (16)$$

$$G_c = (1-\beta_1)G_c^* - \beta_1 G_s^* \quad + \beta_1 p_1 R + \ \beta_1 p_2 A_1 + \beta_1 p_3 A_2 \quad (17)$$

$$R = \beta_3 p_1 (G_c^* - G_c) + \beta_2 R^* + \beta_4 (1-p_1)\left[I_g - (1-p_2)A_1 - (1-p_3)A_2\right] \quad (18)$$

$$I_g = (1-\beta_5)\ I_g^* + \beta_5[(1-p_1)R + (1-p_2)A_1 + (1-p_3)A_2] \quad (19)$$