A LINEAR PROGRAMMING APPROACH TO SOME POLICY PROBLEMS IN GREECE

By
DIMITRIOS N. KOUZIONIS

I. INTRODUCTION

This paper is an application of the Linear Programming (LP) approach to some policy problems in Greece. The discussion concerning the LP approach is to reveal what the main constraint to higher economic growth in Greece is.

Using the reduced form coefficients of an econometric model* of the Greek economy which emphasizes the monetary sector, the results would seem to give support to the importance of the balance of payments constraint (i.e. the import constraint).

II. STRUCTURE OF THE LP MODEL

The objective of the following LP model is to maximize

* The structure of the model is described in a Ph. D. thesis submitted to the University of Kent at Canterbury (1980). The model consisting of 53 equations is estimated by 2SLS principal components method for the period 1958-1974 and is designed to reflect the impact of alternative monetary and fiscal policies. The capital stock and the labour force are considered as given. In detail, explanation of the movements of consumer expenditure brings into the picture income variables, and these in turn produce price variables which are dependent on the money supply. Investment expenditure also brings into the picture credit variables which are dependent on deposit variables which in turn are dependent on income and on interest rates. Finally tax receipts depend upon both tax rates, and the tax base. I owe my thanks to R.J.D. Hill for the valuable suggestions on the content of this paper.
\[ R = \sum_{i=1}^{n} b_i X_i \quad (1) \]

where \( R \) = GNP = Gross National Product

\( b_i \) = objective constants (the reduced form coefficients of the policy variables).

\( X_i \) = Policy variables controlled by the authorities

\( n \) = number of policy variables

Equation (1) is maximized subject to a series of constraints

\[ \sum_{j=1}^{n} a_{ij} \leq c_i, \quad i = 1, 2, \ldots, m \quad (2) \]

where \( a_{ij} \) = coefficient constraints

\( C_i \) = constraint constants

\( m \) = number of constraints

The procedure we follow involves getting the submatrix from the reduced form coefficients that concern the policy variables, and using it in the following way. Maximize the Gross National Product Variable\(^1\) subject to a set of constraints such as, for example, that the policy instruments must not exceed a certain value or that the price level must not exceed a specific value determined by political and social criteria and other economic constraints like import constraints. Each of the constraints expressed in terms of the policy variables will change the solution of the LP programme except when the constraint is redundant.

The policy variables we use are represented in the order that they appear (see Definition of Variables in Appendix A). The range of the assumed changes in the policy variables is one unit for all policy variables except for the rates of indirect and direct taxation, the ratio of obligatory deposits of commercial banks and the ratio of obligatory treasury bills held by commercial banks which are assumed to change by 0.01.

Looking at the relevant row of the GNP of the reduced form coefficients

1. We note that exactly the same procedure can be applied to any other endogenous variable in the model. However, we have chosen one target (i.e. GNP) to which we have applied the LP technique, that is the most important target variable for development purposes.
(see Table 1) we can see that the rates of indirect and direct taxation, the government expenditure variable and the Bank's of Greece credit supply variable are among the most powerful policy instruments. Concerning the interest rate policy variables, we observe that the most powerful of them is the one on credits to manufacturing.

Finally we should point out that in the present article more emphasis should be given on the study of alternative parameter assumptions than on the results obtained with any particular set of parameters.

III. EXPERIMENTS WITH THE L.P. MODEL AND THEIR POLICY IMPLICATIONS

We examine the following cases considering:

a. Different (realistic) values of the policy variables in the appropriate constraints.

b. A variable number of constraints (see Table 1).

In case 1 we included all the policy instruments constraints. The maximum value of GNP is 602566 millions drachmas (m.d.). This is achieved by fixing the policy instruments at their maximum permitted values and equating the values of the other policy instruments to zero. However, this value of GNP is associated with a high value of imports which consequently affects the balance of payments.

Case 2 is more realistic since it is similar to case 1 but we have also imposed an import constraint. The results show the importance of imports in expanding GNP. Analytically in case 2(a) the maximum value of GNP is 369511 m.d.; this is achieved by fixing the values of eleven policy variables. In cases 2(b) and 2(c) we considered realistic values of the policy variables for short-run planning.

In case 3 we included the same constraints as in case 2, but instead of an import constraint we imposed a price constraint (i.e. we do not allow the rate of change of prices to increase more than 25% in case 3(a) and 7% in case 3(b). The price constraint was found to be redundant in case 3(a). However, in case (b) in which we restricted the rate of inflation to less than 7.89% the price constraint became effective. In fact the slack variable of the price constraint is zero in case 3(b) while in case 3(a) is positive. So in an effort to achieve a reduction of the inflation from 7.89% to 7% the GNP has to fall from 602566 m.d. to 541737 m.d.

2. Ceteris paribus the values of the other policy instruments.
<table>
<thead>
<tr>
<th></th>
<th>(Cg + Ig)</th>
<th>T^{ind}</th>
<th>T^{def}</th>
<th>r^{A}</th>
<th>r_{sig-d}</th>
<th>r_{sav-d}</th>
<th>r_{d}</th>
<th>r_{p-S-d}</th>
<th>r_{tr-b}</th>
<th>(r_{red}-r_{tr-b})</th>
<th>r_{G}</th>
<th>RR</th>
<th>Tb^{RR}</th>
<th>(r_{imp}-r_{sav})</th>
<th>Cr^{BG}</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGNP</td>
<td>0.0006</td>
<td>3.191</td>
<td>-2.358</td>
<td>-0.017</td>
<td>-0.058</td>
<td>-0.023</td>
<td>0.0009</td>
<td>0.01</td>
<td>-0.007</td>
<td>-0.004</td>
<td>-0.03</td>
<td>-0.104</td>
<td>-0.04</td>
<td>0.003</td>
<td>0.00015</td>
</tr>
<tr>
<td>Imp</td>
<td>0.95</td>
<td>-142364</td>
<td>-38489</td>
<td>-267</td>
<td>-81</td>
<td>152</td>
<td>14</td>
<td>242</td>
<td>-114</td>
<td>-67</td>
<td>-491</td>
<td>-1607</td>
<td>-671</td>
<td>42</td>
<td>2.39</td>
</tr>
</tbody>
</table>
Case 1
Max GNP

Subject to the constraint that

\[
\begin{align*}
(C + F) & \leq 100000 \\
T_{sav.d} & \leq 10 \\
T_{p.s.d.} & \leq 11 \\
(T_{imp} - T_{sav.d}) & \leq 7 \\
Cr^{BC} & \leq 13000 \\
T_{t.d} & \leq 11 \\
T_{ind} & \leq 0.25 \\
T_{dir} & \leq 0.13 \\
T^A & \leq 7.5 \\
T_{tr.b} & \leq 10.5 \\
(T_{red} - T_{sav.d}) & \leq 4 \\
T_M & \leq 13 \\
RR^{cb} & \leq 0.25 \\
T_{b}^{NB} & \leq 0.40 \\
T_{sig.d} & \leq 1 \\
\end{align*}
\]

the results from the above program are:

\[
\begin{align*}
(C + F) & = 100000 \\
T_{sav.d} & = 10 \quad S_2 = 0 \\
T_{p.s.d.} & = 11 \quad S_3 = 0 \\
(T_{imp} - T_{sav.d}) & = 7 \quad S_4 = 0 \\
Cr^{BC} & = 13000 \quad S_5 = 0 \\
T_{t.d} & = 11 \quad S_6 = 0 \\
T_{ind} & = 0 \quad S_7 = 0.25 \\
T_{dir} & = 0 \quad S_8 = 0.13 \\
T^A & = 0 \quad S_9 = 7.5 \\
T_{tr.b} & = 0 \quad S_{10} = 10.5 \\
(T_{red} - T_{sav.d}) & = 0 \quad S_{11} = 4 \\
T_M & = 0 \quad S_{12} = 13 \\
RR^{cb} & = 0 \quad S_{13} = 0.25 \\
T_{b}^{RR} & = 0 \quad S_{14} = 0.4 \\
T_{sig.d} & = 0 \quad S_{15} = 1 \\
\end{align*}
\]

With optimum value of the maximizing function being \( \text{Max GNP} = 602565 \)
## Table 2 (Cont.)

Linear Programming Problem

Max GNP

Subject to the constraints that

<table>
<thead>
<tr>
<th></th>
<th>case (a)</th>
<th>case (b)</th>
<th>case (c)</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_i$</td>
<td>≤ 100000</td>
<td>≤ 100000</td>
<td>≤ 100000</td>
<td>w</td>
</tr>
<tr>
<td>$x_{sav.d}$</td>
<td>≤ 10</td>
<td>≤ 10</td>
<td>≤ 10</td>
<td></td>
</tr>
<tr>
<td>$x_{p.s.d}$</td>
<td>≤ 21</td>
<td>≤ 21</td>
<td>≤ 21</td>
<td></td>
</tr>
<tr>
<td>$(x_{sav.d})'c_{bc}$</td>
<td>≤ 7</td>
<td>≤ 7</td>
<td>≤ 7</td>
<td></td>
</tr>
<tr>
<td>$x_{a}$</td>
<td>≤ 13</td>
<td>≤ 11</td>
<td>≤ 11</td>
<td></td>
</tr>
<tr>
<td>$x_{ind}$</td>
<td>≤ 0.25</td>
<td>≤ 0.25</td>
<td>≤ 0.25</td>
<td></td>
</tr>
<tr>
<td>$x_{dir}$</td>
<td>≤ 0.25</td>
<td>≤ 0.13</td>
<td>≤ 0.25</td>
<td></td>
</tr>
<tr>
<td>$x^a$</td>
<td>≤ 7.5</td>
<td>≤ 7.5</td>
<td>≤ 7.5</td>
<td></td>
</tr>
<tr>
<td>$x_{drb}$</td>
<td>≤ 10.5</td>
<td>≤ 10.5</td>
<td>≤ 10.5</td>
<td></td>
</tr>
<tr>
<td>$(x_{sav.d})'b_{bc}$</td>
<td>≤ 1</td>
<td>≤ 1</td>
<td>≤ 1</td>
<td></td>
</tr>
<tr>
<td>$x_{b}$</td>
<td>≤ 13</td>
<td>≤ 13</td>
<td>≤ 13</td>
<td></td>
</tr>
<tr>
<td>$x_{drb}$</td>
<td>≤ 0.4</td>
<td>≤ 0.4</td>
<td>≤ 0.4</td>
<td></td>
</tr>
<tr>
<td>$x_{sig.d}$</td>
<td>≥ 1</td>
<td>≥ 1</td>
<td>≥ 1</td>
<td></td>
</tr>
<tr>
<td>Imports</td>
<td>≤ 80000</td>
<td>≤ 120000</td>
<td>≤ 100000</td>
<td></td>
</tr>
</tbody>
</table>

The results from the above program are:

<table>
<thead>
<tr>
<th></th>
<th>case (a)</th>
<th>case (b)</th>
<th>case (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_i$</td>
<td>100000</td>
<td>100000</td>
<td>100000</td>
</tr>
<tr>
<td>$x_{sav.d}$</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>$x_{p.s.d}$</td>
<td>7</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>$(x_{sav.d})'c_{bc}$</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>$x_{a}$</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>$x_{ind}$</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>$x_{dir}$</td>
<td>0.25</td>
<td>0.23</td>
<td>0.25</td>
</tr>
<tr>
<td>$x^a$</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>$x_{drb}$</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5</td>
</tr>
<tr>
<td>$(x_{sav.d})'b_{bc}$</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$x_{b}$</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>$x_{drb}$</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>$x_{sig.d}$</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Imports</td>
<td>80000</td>
<td>120000</td>
<td>100000</td>
</tr>
</tbody>
</table>

With optimal value of the right-hand side being 100000.
Subject to the constraint that

\[
\begin{align*}
[C_1 + 1] & \leq 200000 \\
T_{\text{acid}} & \leq 10 \\
T_{\text{base}} & \leq 11 \\
\left(\frac{\text{F}_{\text{mean}}}{\text{F}_{\text{acid}}}ight) & \leq 7 \\
C_{\text{Na}} & \leq 12000 \\
F_{\text{g}} & \leq 12 \\
F_{\text{inc}} & \leq 0.15 \\
F_{\text{dir}} & \leq 9.5 \\
F_{\text{tr.h}} & \leq 10.5 \\
\left(\frac{\text{F}_{\text{mean}}}{\text{F}_{\text{acid}}}ight) & \leq 3 \\
F_{R} & \leq 13 \\
F_{R_{\text{mix}}} & \leq 0.75 \\
F_{R_{\text{M}}} & \leq 0.8 \\
F_{\text{acid}} & \leq 1 \\
F_{\text{mix}} & \leq 7 
\end{align*}
\]

The results from the above programs are:

\[
\begin{align*}
[C_1 + 1] & \leq 30000 \\
T_{\text{acid}} & = 10 \\
T_{\text{base}} & = 11 \\
\left(\frac{\text{F}_{\text{mean}}}{\text{F}_{\text{acid}}}ight) & = 7 \\
C_{\text{Na}} & = 12000 \\
F_{\text{g}} & = 12 \\
F_{\text{inc}} & = 0.15 \\
F_{\text{dir}} & = 9.5 \\
F_{\text{tr.h}} & = 10.5 \\
\left(\frac{\text{F}_{\text{mean}}}{\text{F}_{\text{acid}}}ight) & = 3 \\
F_{R} & = 13 \\
F_{R_{\text{mix}}} & = 0.75 \\
F_{R_{\text{M}}} & = 0.8 \\
F_{\text{acid}} & = 1 \\
F_{\text{mix}} & = 7 
\end{align*}
\]

Max CIP

<table>
<thead>
<tr>
<th>\text{case (a)}</th>
<th>\text{case (b)}</th>
</tr>
</thead>
</table>
| \[C_1 + 1\]    | \leq 30000      | \leq 30029  \\
| \text{acid}    | \geq 10         | \geq 10     \\
| \text{base}    | \geq 11         | \geq 11     \\
| \left(\frac{\text{F}_{\text{mean}}}{\text{F}_{\text{acid}}}ight) | \leq 7         | \leq 3       \\
| \text{Na}      | \leq 12000      | \leq 12000  \\
| \text{g}       | \leq 12         | \leq 12     \\
| \text{inc}     | \leq 0.15       | \leq 0.15   \\
| \text{dir}     | \leq 9.5        | \leq 9.5    \\
| \text{tr.h}    | \leq 10.5       | \leq 10.5   \\
| \left(\frac{\text{F}_{\text{mean}}}{\text{F}_{\text{acid}}}ight) | \leq 3       | \leq 3       \\
| \text{R}       | \leq 13         | \leq 13     \\
| \text{R}_{\text{mix}} | \leq 0.75    | \leq 0.75   \\
| \text{R}_{\text{M}} | \leq 0.8        | \leq 0.8    \\
| \text{acid}    | \leq 1          | \leq 1      \\
| \text{mix}     | \leq 7          | \leq 7      

Max CIP

\[
\begin{align*}
\text{Max CIP} & \geq \text{optimization function value} \\
\text{Max CIP} & \geq 13.44
\end{align*}
\]

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### TABLE 2 (Cont.)

<table>
<thead>
<tr>
<th>Case (a)</th>
<th>Case (b)</th>
<th>Case (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( [c + e] )</td>
<td>( \leq 100000 )</td>
<td>( \leq 100000 )</td>
</tr>
<tr>
<td>( t_{\text{av.d}} )</td>
<td>( \leq 10 )</td>
<td>( \leq 10 )</td>
</tr>
<tr>
<td>( r_{\text{p.d}} )</td>
<td>( \leq 11 )</td>
<td>( \leq 11 )</td>
</tr>
<tr>
<td>( t_{\text{p.d}} )</td>
<td>( \leq 7 )</td>
<td>( \leq 7 )</td>
</tr>
<tr>
<td>( t_{\text{omd}} )</td>
<td>( \leq 13000 )</td>
<td>( \leq 13000 )</td>
</tr>
<tr>
<td>( T_{\text{omd}} )</td>
<td>( \leq 11 )</td>
<td>( \leq 11 )</td>
</tr>
<tr>
<td>( v_{\text{omd}} )</td>
<td>( \leq 0.25 )</td>
<td>( \leq 0.25 )</td>
</tr>
<tr>
<td>( n_{\text{omd}} )</td>
<td>( \geq 0.13 )</td>
<td>( \geq 0.13 )</td>
</tr>
<tr>
<td>( A )</td>
<td>( \geq 7.5 )</td>
<td>( \geq 7.5 )</td>
</tr>
<tr>
<td>( F_{\text{omd}} )</td>
<td>( \leq 10.5 )</td>
<td>( \leq 10.5 )</td>
</tr>
<tr>
<td>( (\text{real} - \text{av.d}) )</td>
<td>( \geq 4 )</td>
<td>( \geq 4 )</td>
</tr>
<tr>
<td>( T_{\text{omd}} )</td>
<td>( \leq 13 )</td>
<td>( \leq 13 )</td>
</tr>
<tr>
<td>( B_{\text{omd}} )</td>
<td>( \geq 0.25 )</td>
<td>( \geq 0.25 )</td>
</tr>
<tr>
<td>( T_{\text{ob}} )</td>
<td>( \geq 0.4 )</td>
<td>( \geq 0.4 )</td>
</tr>
<tr>
<td>( t_{\text{sig.d}} )</td>
<td>( \geq 1 )</td>
<td>( \geq 1 )</td>
</tr>
<tr>
<td>( \text{Imports} )</td>
<td>( \leq 100000 )</td>
<td>( \leq 50000 )</td>
</tr>
<tr>
<td>( \text{GDP} )</td>
<td>( \leq 6 )</td>
<td>( \leq 6 )</td>
</tr>
</tbody>
</table>

The results from the above program are:

<table>
<thead>
<tr>
<th>Case (a)</th>
<th>Case (b)</th>
<th>Case (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( [c + e] )</td>
<td>( = 97466 )</td>
<td>( 99070 )</td>
</tr>
<tr>
<td>( t_{\text{av.d}} )</td>
<td>( s_1 = 10711 )</td>
<td>( s_1 = 9 )</td>
</tr>
<tr>
<td>( r_{\text{p.d}} )</td>
<td>( s_2 = 0 )</td>
<td>( s_2 = 0 )</td>
</tr>
<tr>
<td>( t_{\text{p.d}} )</td>
<td>( s_3 = 11 )</td>
<td>( s_3 = 11 )</td>
</tr>
<tr>
<td>( t_{\text{omd}} )</td>
<td>( s_4 = 7 )</td>
<td>( s_4 = 7 )</td>
</tr>
<tr>
<td>( t_{\text{omd}} )</td>
<td>( s_5 = 0 )</td>
<td>( s_5 = 0 )</td>
</tr>
<tr>
<td>( T_{\text{omd}} )</td>
<td>( s_6 = 0 )</td>
<td>( s_6 = 0 )</td>
</tr>
<tr>
<td>( v_{\text{omd}} )</td>
<td>( 0.0000 )</td>
<td>( 0.000 )</td>
</tr>
<tr>
<td>( n_{\text{omd}} )</td>
<td>( 0.2214 )</td>
<td>( 0.2214 )</td>
</tr>
<tr>
<td>( A )</td>
<td>( s_7 = 0 )</td>
<td>( s_8 = 0 )</td>
</tr>
<tr>
<td>( F_{\text{omd}} )</td>
<td>( s_9 = 0 )</td>
<td>( s_9 = 0 )</td>
</tr>
<tr>
<td>( t_{\text{omd}} )</td>
<td>( s_{10} = 0 )</td>
<td>( s_{10} = 0 )</td>
</tr>
<tr>
<td>( t_{\text{omd}} )</td>
<td>( s_{11} = 0 )</td>
<td>( s_{11} = 0 )</td>
</tr>
<tr>
<td>( T_{\text{omd}} )</td>
<td>( s_{12} = 0 )</td>
<td>( s_{12} = 0 )</td>
</tr>
<tr>
<td>( B_{\text{omd}} )</td>
<td>( s_{13} = 0 )</td>
<td>( s_{13} = 0 )</td>
</tr>
<tr>
<td>( T_{\text{ob}} )</td>
<td>( s_{14} = 0 )</td>
<td>( s_{14} = 0 )</td>
</tr>
<tr>
<td>( t_{\text{sig.d}} )</td>
<td>( s_{15} = 0 )</td>
<td>( s_{15} = 0 )</td>
</tr>
<tr>
<td>( \text{Imports} )</td>
<td>( s_{16} = 0 )</td>
<td>( s_{16} = 0 )</td>
</tr>
<tr>
<td>( \text{GDP} )</td>
<td>( s_{17} = 0 )</td>
<td>( s_{17} = 0 )</td>
</tr>
</tbody>
</table>

With optimal value of the remaining function being

Max GDP = 1400566

Max GDP = 1400566

Max GDP = 1400566

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Finally case 4 is similar to case 1, but we have also imposed both import and price constraint. The results revealed again the dominance of the import constraint. However, in case 4(c) the slack variable of the import constraint takes a value which is not equal to zero because of the restrictive value of the government expenditure constraint.

On the other hand the price constraint became a non redundant constraint at a rate of inflation of less than 7.89%. So the price constraint is not an obstacle in the expansion of the GNP unless we want to keep the rate of inflation at this level.

Obviously the above mentioned results are dictated by the structure of the model.

IV. CONCLUSION

The discussion concerning the linear programming approach reveals that the main obstacle to higher economic growth in Greece is the balance of payments; this indicates the importance of the import constraint in expanding GNP and that the price constraint does not constitute a serious obstacle in the effort to maximize GNP. So in an effort to expand GNP in the future, the authorities must be aware of the repercussions of this expansion of GNP on the balance of payments rather than on the rate of inflation (though this depends on the value they attach to lower inflation).

REFERENCES


DEFINITION OF VARIABLES

Policy Instruments

1. \((Gg+Ig)\)  Government consumption plus government investment at constant 1970 prices.
2. \(T^{ind}\)  Ratio of total indirect taxes to private consumption.
3. \(T^{dir}\)  Ratio of total direct taxes on income to National Income.
4. \(r^A\)  Interest rate on credits to farmers.
5. \(r_{\text{Sig.d}}\)  Interest rate on sight deposits.
6. \(r_{\text{sav.d}}\)  Interest rate on savings deposits.
7. \(rt-d\)  Interest rate on time deposits.
8. \(r_{\text{p..j.}}\)  Interest rate on postal savings deposits.
9. \(rt\)  Interest rate on treasury bills.
10. \((r_{\text{red}}-r_{\text{sav.d}})\)  Bank of Greece rediscount interest rate minus interest rate on savings deposits.
11. \(rM\)  Weighted average interest rate on credits to bills discount, working capital, handicraft and long term credit.
12. \(RR\)  Ratio of obligatory deposits of commercial banks with the Bank of Greece to bills discounted credit plus working capital credit plus trade credit supplied by commercial banks for the years (1966 - 1974).
13. \(Tb^{RR}\)  Ratio of obligatory treasury bills held by commercial banks to total sight and savings deposits with commercial banks.
14. \((r_{\text{imp}}-r_{\text{sav.d}})\)  Interest rate on credits to trade supplied by commercial banks minus interest rate on savings deposits.
15. \(Cr^{BG}\)  Flow of supply of credit of Bank of Greece and of Government deflated by PGDP.
Endogenous variables

1. GNP  Gross National Product at constant 1970 prices.
2. PGNP  Percentage rate of growth of the implicit Gross National Product price index.
3. $I_{mp}$  Imports of goods and services deflated by the import price index.