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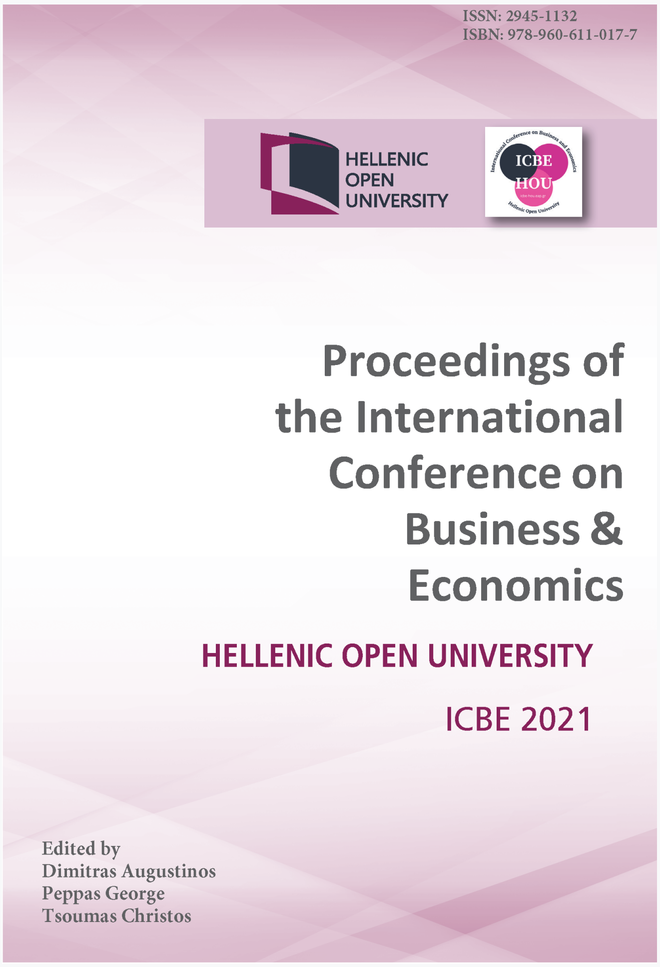

Controlling GDP and Debt with a Post-Keynesian model

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Controlling Greek GDP and Debt with a Post-Keynesian model

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Abstract

Our aim in this paper is to design a set of fiscal policy rules using a linear, discrete macroeconomic Post-Keynesian model with delays. We develop algebraic methods with appropriate symbolic algorithms that produce a solution, which allows us to find a path for the desired GDP and debt targets to be met.

1 Introduction

Following the fall of the Keynesian era, its economic policies along the government role began to be challenged by the literature. With financial liberalization as the

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main target, expansionary fiscal policy was rejected as it was causing rigidities in the capital market and literature turned to researches correlating fiscal policy and growth. In the 90's and the early 00's fiscal consolidation was considered the main tool for stimulating the economy. Under the assumptions Say's law, the main determinant of economic growth is supply, while demand is adjected to it. So any cuts in government expenditures that according to Keynesian theory should be expected to cause reduction in the level of the aggregate demand, in the mainstream theory is expected to produce the opposite, i.e. growth. (Giavazzi and Pagano (1990), Bertola and Drazen (1993), Alesina and Perotti (1995), et al (1998), Ardagna (2004)).

Economic policy at the start of the "Great Recession" was at a crossroads, as policymakers had to choose between two options: to sustain the still modest and fragile economic recovery with expansionary policies that should promote employment; or to undertake fiscal adjustment to cope with public deficits and debt levels viewed as excessively high that could undermine the confidence of financial markets and prompt a new financial crisis. The latter was chosen and the aftermath of the 2008 Recession showed that fiscal consolidation, which used as the main instrument to control the impact of the crisis, failed to provide the declared purposes of stability and growth. The need for a sustainable path for all the economies, and especially for the one with high debt-to-GDP ratio was required immediately and stimulating the economy in crisis became the focus of the bibliography. Over the last decades, many Post-Keynesian models have focused on expansionary fiscal policies and argue that the economy can be stimulated by fiscal policy interventions. (Hein and Stockhammer (2011), Allain (2015), Tavani and Zamparelli (2017), Ko (2018)). In an economy that sets policy targets, the desired path to approach them is of high importance. Mathematical control theory literature has produced a tool for tracking an economic system, and for more than half a century, feedback control has been utilized in order to find a desired path for the policy targets and important results have been derived. (e.g., Kendrick (1993), Kotsios and Leventidis (2004), Kostarakos and Kotsios (2018)).

This paper aims to address the issue of designing fiscal policy rules to achieve GDP growth and debt reduction. In the last decade of the "great recession" many countries, Greece between them, experienced austerity measures in order for the public debt to follow a sustainable path. We propose that instead of austerity, expansionary fiscal policy and in particular, appropriate changes in government expenditures could lead the economy to achieve the targets for GDP and debt.

The analysis is conducted within a linear, deterministic variant of a Post-Keynesian model proposed by Kalecki (1971) and further developed by the Post-Keynesian literature, with some innovations we introduced,. Arestis (2011), Hein (2018).

Our results indicate that an economy like Greece in early 2010, facing a high debt-to-GDP ratio, should implement expansionary fiscal policy plans, instead of austerity measures that was implemented, to ensure positive GDP growth rates and debt reduction. We propose that if Greece in early 10's had focused on government expenditures and a labor oriented taxation system, GDP growth and debt sustainability could be achieved simultaneously. The paper is organized as follows. In 2 we present the model. 3 presents the relevant algorithms. In 4 we provide the counterfactual policy experiments. 6 Are the conclusions.

2 The Model

Over the past decades, multiple Post-Keynesian models have been developed, demonstrating that expansionary fiscal policies can be an effective instrument on the hands of policy makers.Post Keynesian short-run macroeconomic models and the macroeconomic policy implications derived from these models over the last decades, or so, have increasingly focused on active fiscal policies, government deficits, and debt, when it comes to stabilizing the economy, both in the short and the long run (Alesina and Sawyer (2003), Alesina and Sawyer (2004), Setterfield (2007), Fontana (2009), Hein and Stockhammer (2011)). In these models, dynamic analysis is conducted in order to show the effectiveness of government expenditures and whether privet investment crowds-out or not. Hein (2018) shows that government expenditures can provide economic growth and fiscal deficits do not accumulate affecting debt dynamics negatively. Moreover, he argues that distribution of income is crucial for GDP growth. Our analysis deviates from the Post-Keynesian in the methodology that is used in these previously mentioned bibliography. Implementing feedback control methods and setting targets at GDP and debt for each period, we control the actual GDP and debt through government expenditures. The solution technique is parameterized and thus it allows for proper symbolic algorithms to be developed. However, the most important advantage is that based on these algorithms, a whole class of fiscal policy rules for solving the policy problems at hand can be designed enabling the policymaker to choose the rules that are the most appropriate based on different criteria. Nonetheless, this approach serves as a guideline of what the 'optimal'path for the policy instruments should be (optimal in the sense that complete tracking, without delay, of the target sequence is achieved).

Following You and Dutt (1996), we assume that the government finances budget deficits only by borrowing. In addition, we follow Ko (2018) in assuming that the economic system is closed and that workers have zero propensity to save, while capitalists save a constant fraction of their disposable income and earn interest revenue by purchasing government bonds. Under these assumptions, workers only earn a wage income and capitalists earn a profit and an interest income. Let us assume income distribution as given, and let us split workers' consumption into two parts, one related to capitalists' expenditure and the other to government expenditure. Given the distribution of income, the workers' consumption induced by capitalist expenditure will remain constant if the latter does not change. Accordingly, the increase in government spending (that is equivalent to an increase in the budget deficit) will induce a direct -through its purchases- and indirect -through higher workers' spending- increase in the aggregate demand, which will give rise to greater output, profits and wages.

Under these assumptions, workers earn a wage income and capitalists earn a profit and an interest income.

As already stated, we opted for a linear, deterministic model of the macroeconomy, which will allow us to thoroughly assess the effects of the proposed policy plan. Particularly, we use a variant of a Kaleckian model, introduced by Kalecki, coupled with the government budget constraint, in which we expanded using time delays.

Assuming a closed economy, the income identity is:

$$Y(t) = C(t) + I(t) + \lambda_0 G(t) + \lambda_1 G(t-1) \tag{1}$$

In this model, following Kostarakos and Kotsios (2018), we argue that the government's decision to spend in period t is not immediately realized into outlays. Thus, the parameters λ_0, λ_1 indicate the percentage of the government's decision to spend in period t that is disbursed in period $t+i$. These are the well known "lags" of fiscal policy.

Regarding the behavioral equations, we follow Ko (2018) in assuming that consumption is divided between workers and capitalists. So, $C(t) = (1-t_l)L(t) + (1-s)(1-t_c)(W_C(t) + rB(t-1))$

Where C is consumption, L is labor income, W_c is capitalist's income, t_w is the tax rate for wage income, t_c is the tax rate for capital income, $s \in (0,1)$ is capitalist's propensity to save, r is the nominal interest rate, B is government debt and $rB(t-1)$ represents the interest income of capitalists by purchasing government bonds. This represents that capitalists earn additional interest income with the rise in interest rates or in the government debt and thus increase their consumption expenditure.

Regarding the investment, we assume that it depends in the investment rate, k, and the last period's GDP, that is: $I(t) = kY(t-1)$

The budget constraint of the government has the standard form:

$B(t) = B(t-1) + rB(t-1) + G(t) - T_L(t) - T_C(t)$

where $B(t)$ denotes debt outstanding, r is the interest rate and $T_L(t) = t_l L(t), T_C(t) = t_c W_C(t)$

where $T_l(t)$ and $T_c(t)$ are the revenues from labour and capital taxation respectively.

After manipulation, we end up to a system of two equations with one input, $G(t)$ and two outputs,$Y(t), B(t)$

$$Y(t) = \alpha_1 Y(t-1) + \alpha_2 B(t-1) + G(t)\lambda_0 + \lambda_1 G(t-1) \tag{2}$$

$$B(t) = \beta_1 Y(t-1) + \beta_2 B(t-1) + G(t) \tag{3}$$

where, $\alpha_1 = (h(s-1)\tau_c + g(-\tau_c) + g - hs + h + k)$, $\alpha_2 = r(s-1)(\tau_c - 1)$, $\beta_1 = (h\tau_c + g\tau_c)$, $\beta_2 = (r+1)$

This discrete system can be rewritten more compactly via utilizing the state-space form. In order to write (2),(3) in their state-space form, we introduce the state vector:

$$\vec{x}(t) = \begin{bmatrix} Y(t) \\ B(t) \end{bmatrix}, \vec{u}(t) = \begin{bmatrix} G(t) \\ G(t-1) \end{bmatrix} \tag{4}$$

, and thus

$$\vec{x}(t) = A\vec{x}(t-1) + B\vec{u}(t) \tag{5}$$

$$\vec{x}(t) = A\vec{x}(t-1) + \begin{bmatrix} \lambda_0 & \lambda_1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} G(t) \\ G(t-1) \end{bmatrix} \tag{6}$$

We incorporate flexible targets theory, developed by Theil (1956) (i,e $Y^*(t)$,$B^*(t)$, should be approached as close as possible, but not necessarily attained exactly) which will allow us to discriminate between paths that are feasible and those which are impractical. With $Y^*(t)$,$B^*(t)$ and all the parameters given, we want to calculate a dynamical path for $G(t)$ so that the $Y(t)$,$B(t)$ produced by our model approach $Y^*(t)$,$B^*(t)$ in a maximum way. To formulate that we introduce the equation of total error, which will serve us as the objective function. Solving a tracking problem in which the tracking error is minimized, the following equation holds.

$$\min \sum_{i=1}^{n} ((Y[t] - Y^*[t])^2 + (B[t] - B^*[t])^2) \tag{7}$$

with respect to $G(t)$, where $Y^*(t)$ and $B^*(t)$ denote the desired levels of GDP and public debt respectively and are predefined for each period, and $Y(t)$, $B(t)$ are the produced output of our model for GDP and debt.

2.1 Controllability

In this particular discrete system of equations, we need to examine whether feedback policy rules, in order to approach our targets, exist. Specifically, we need confirmation that by appropriately manipulating the available imports, we can lead the system to a desired position, in a finite time interval. Hence, we need to examine whether the system is controllable.

Theorem 1 A system $\mathbf{x}(t+1) = A\mathbf{x}(t) + B\mathbf{u}(t)$ where $A_{k\times k}, B_{k\times m}$, is controllable if and only if the rank of the controllability matrix W, where $W_{m\times km} = [B, AB, A^2B, ...A^{k-1}B]$, is equal to k.

As we know, the system is controllable if and only if the $n \times nm$ controllability matrix has rank n, i.e., full row rank. By using this theorem (2.1) we can easily prove the following property. System 6 is controllable. (See 9)

3 The Algorithm

In order to solve the problem of designing appropriate fiscal policy rules we have developed an algorithmic procedure. This algorithm produces the relevant desired system for the model at hand.

Input: The parameters h, s, k, r, t_l, t_c, g, are the initial conditions: $Y(0)$,$B(0)$,$G(0)$ and the reference sequences $Y^*(t)$,$B^*(t)$

Output: The desired levels of $G(t)$, $t = 0, .., n$

Step 1: Calculate the cumulative error $V = \sum_{i=1}^{n}((Y(t)-Y^*(t))^2+(B(t)-B^*(t))^2)$ which serves as the objective function

Step 2: Calculate $\frac{dV}{dG(t)}$, $t = 1, .., n$

Step 3: Solve the system, $\frac{dV}{dG(t)} = 0$, with respect to $G(t)$, $t = 1, ..., n$

4 Simulations and Experiments

We present some policy experiments that will allow us to examine the effects of the proposed methodology for annually fiscal design on the system. Our starting point for the levels of GDP and debt are conducted from their actual values of Greece at 2010. The target levels of GDP and debt, are denoted by $Y^*(t), B^*(t)$ respectively. In the first part, we present some extreme taxation scenarios, where we examined the outputs for various values of t_c and t_l, in order to gain some insight into the effects of taxation of both classes (capitalists and workers) in fiscal policy implementation. Specifically, the following figures present the outcomes of GDP and debt (denoted by Y and B), for different values of t_c and t_l, along with the government expenditures divided by the actual GDP. The policy targets and starting points are :

- GDP growth 1%, $Y(0) = 240$
- B reduction 1%, $B(0) = 302$
- $Y^*(t)$,$B^*(t)$

4.1 Experiment 1 **Where capital taxation is constant and labor taxation varies**

The "low capital taxation" : here, we assume that capital tax is fixed at 10% and we present the outcomes for GDP, Debt and Government expenditures as a percentage of GDP, for three different values for labor tax, as well as the targets values for GDP and Debt, denoted by $Y^*(t)$, $B^*(t)$ respectively :

1. labor tax is 15% 2. labor tax is 35% 3. labor tax is 55%

Figures 1, 2, 3 present the time path for three different outcomes of GDP, Debt and their targets along with Government expenditures over GDP, which are calculated under different specifications for the t_c and t_l parameters.

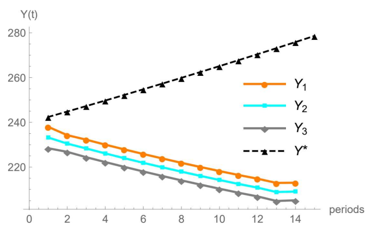

Figure 1: GDP

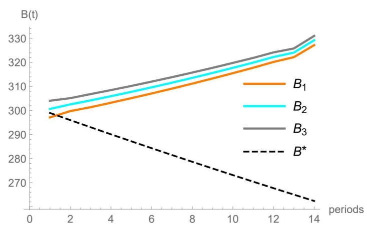

Figure 2: Debt

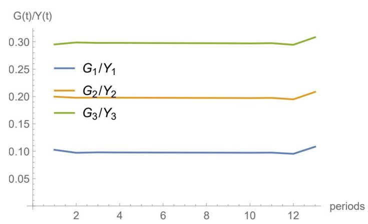

Figure 3: G/GDP

It is evident from the figures 1, 2 and 3, that for the first where the capital tax is fixed at the very low value of 10%, there is no path approaching the targets for GDP and Debt. This happens because consumption plays a vital role on GDP. As labors consume all their income, with extreme levels of labor taxation, labor's income decreases sufficiently and thus, consumption is not able to stimulate GDP growth. In addition, there is no point where government expenditures can affect actual GDP in approaching the targets as with this low levels of capital taxation, government has vastly decreased its income which is taxation and thus, there are not enough funds for government expenditures. In addition, it is important to note that in all cases, GDP and Debt seem to follow the actual values of Greece during the "Great Recession". Even in case 1 where government expenditures are extremely low, as fiscal consolidation theory suggests, Debt over GDP ratio rises in extreme levels. It appears that distribution of income through taxation needs to take place, as the increasing gap between the two classes' income is contractionary for the values of GDP and debt. Low capital taxation might be able to stimulate private investment but in both short and long run, the latter cannot be absorbed due to lack of consumption.

4.2 Experiment 2 **Where labor taxation is constant and capital taxation varies**

The "low labor taxation scenario" : here, we assume that labor tax is fixed at 10% and capital tax takes three different values : 1. capital tax is 15% 2. capital tax is 35% 3. capital tax is 55%

Figures 4, 5, 6 present the time path for three different outcomes of GDP, Debt and their targets along with Government expenditures over GDP, which are calculated under different specifications for the t_c and t_l parameters.

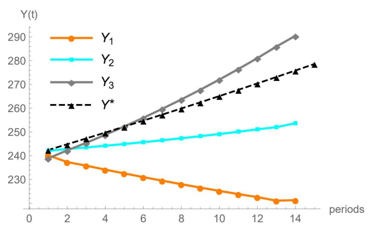

Figure 4: GDP

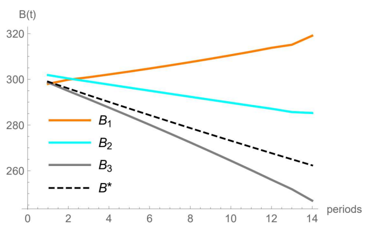

Figure 5: Debt

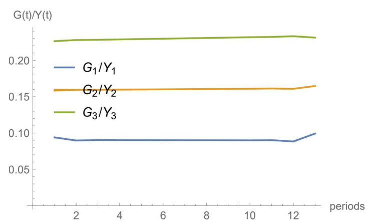

Figure 6: G/GDP

On the other hand, we observe from the second scenario via figures 4, 5 and 6, where labor tax is fixed at a very low level of 10%, that we are provided with different results. In the second and third cases where capital taxation is at 35% and 55% there, appear to be paths of GDP growth along Debt reduction. These results fall into the Post-Keynesian theory, as consumption is the variable stimulating the economy. A rise in consumption is followed by a rise in investment as there is excessive demand in the economy. Capitalists hire more employees in order to meet this gap aggregate demand, so full employment is achieved, and in addition, their profits exceed their loss from the tax hikes with results to keep investment in high values.

Another important issue that can be extracted from the figure, is that as taxation rises, the amount of government spending as a percentage of GDP increases as well. That is because higher taxation leads to lower consumption which is vital for the growth of GDP. So government expenditures fulfill the gap generated into the economy, but in high levels of taxation, G/GDP reach high limits that probably cannot be applied.

Moreover, our experiment indicates that, government expenditures need to take place in order for the GDP growth, debt's decline and approaching the targets. Specifically, it appears that for values around 30% of GDP, government expenditures produce the best outcomes for the model. This, indicates that potentially in the years of the "Great Recession", Greece could choose to follow a different path than austerity, as there appears that expansionary fiscal policy could lead the economy to GDP growth along with debt sustainability.

5 Concluding Remarks and Possible Extensions of the Model

The results presented here are based on a simple Post-Keynesian model, with some innovations we introduced. These innovations are the time delays as government's decision is not immediately realized into outlays, the divide of the economy between two classes, capitalists and workers, and the consumption function where we assume that capitalists earn profit by purchasing government bonds. This model is highly tractable and allows us to divide the economy in two classes, capitalists and labors. This, combined with the feedback control method has never been applied in earlier works in the literature and leaves space for further exploration and utilization of the mathematical control theory. We are currently working on using a different methodology within the specific model. Following the mathematical control theory we are implementing the adaptive control technique, which will allow us to design fiscal policy rules for government expenditures so that desired target-levels for GDP are exactly met (that is, complete tracking is achieved).

6 Concluding Results

Our aim in this paper was to present a computational approach, for the design of fiscal policy rules. The results presented here, along with the fiscal policy implications are extracted by the mathematical feedback control. We measure the size of government expenditures per period according to the minimization of the objective function. This method provides us with an approximation of the output to be as close to the target as possible. So for the next step, we find which combination of government expenditures and (fixed) tax rates produces the 'best' result in terms of divergence. Thus, we are allowed to choose the best fitting policy for according the targets along with whether the policy in need is feasible. The feedback framework implemented in this paper, ensures us that the policy maker can be active and provide a smooth transition path to a positive growth. Our results follow the Post-Keynesian literature in providing insight of the need of an active expansionary fiscal policy, and countries like Greece, facing an economic crisis, can reverse the downturn if act accordingly. On contrary, if austerity is implemented, as recent years showed, the paths for GDP and Debt are contractionary. It appears that fiscal policy can impact the economy, if used properly. Fiscal policy tools, taxation and government expenditures can become an efficient instrument for the policy maker, especially for a country like Greece, which suffers from a high debt accumulation.

7 Appendix A

List of Tables for the first scenario

Table 1: labor tax is 0.15%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	237.969	242.4	297.131	298.98	0.0701394
2	234.275	244.824	299.743	295.99	0.102598
3	232.246	247.272	301.367	293.03	0.0971836
4	230.023	249.745	303.222	290.1	0.0979708
5	227.906	252.242	305.111	287.199	0.0977473
6	225.845	254.765	307.066	284.327	0.0976887
7	223.847	257.312	309.084	281.484	0.0976032
8	221.912	259.886	311.164	278.669	0.0975223
9	220.038	262.484	313.308	275.882	0.0974393
10	218.227	265.109	315.518	273.123	0.0973664
11	216.468	267.76	317.779	270.392	0.0972312
12	214.82	270.438	320.183	267.688	0.0974862
13	212.919	273.142	322.175	265.011	0.0953056
14	213.016	275.874	327.189	262.361	0.108236
15	201.165	278.633	313.965	259.738	0.0235092

Table 2: labor tax is 0.35%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	233.226	242.4	300.642	298.98	0.189523
2	230.488	244.824	302.543	295.99	0.199717
3	228.31	247.272	304.181	293.03	0.19772
4	226.104	249.745	305.938	290.1	0.197964
5	223.977	252.242	307.746	287.199	0.197797
6	221.909	254.765	309.619	284.327	0.197704
7	219.903	257.312	311.553	281.484	0.197598
8	217.958	259.886	313.55	278.669	0.197494
9	216.072	262.484	315.61	275.882	0.197386
10	214.249	265.109	317.736	273.123	0.197295
11	212.472	267.76	319.908	270.392	0.197109
12	210.825	270.438	322.252	267.688	0.19745
13	208.847	273.142	324.067	265.011	0.194866
14	209.064	275.874	329.214	262.361	0.208394
15	197.593	278.633	316.465	259.738	0.129642

Table 3: labor tax is 0.55%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	228.411	242.4	304.049	298.98	0.313508
2	226.81	244.824	305.126	295.99	0.295163
3	224.409	247.272	306.827	293.03	0.298755
4	222.244	249.745	308.475	290.1	0.297871
5	220.105	252.242	310.207	287.199	0.297901
6	218.033	254.765	311.996	284.327	0.297744
7	216.02	257.312	313.848	281.484	0.297624
8	214.066	259.886	315.763	278.669	0.297496
9	212.171	262.484	317.739	275.882	0.297364
10	210.338	265.109	319.785	273.123	0.297258
11	208.544	267.76	321.865	270.392	0.297016
12	206.903	270.438	324.154	267.688	0.297449
13	204.852	273.142	325.793	265.011	0.294509
14	205.161	275.874	331.027	262.361	0.308276
15	194.141	278.633	318.882	259.738	0.23622

8 Appendix B

List of Tables for the second scenario

Table 4: capital tax is 0.15%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	240.155	242.4	297.985	298.98	0.068059
2	237.316	244.824	299.826	295.99	0.093963
3	235.806	247.272	300.877	293.03	0.0897302
4	234.134	249.745	302.113	290.1	0.0903648
5	232.538	252.242	303.379	287.199	0.0902158
6	230.981	254.765	304.701	284.327	0.0901925
7	229.467	257.312	306.073	281.484	0.0901484
8	227.996	259.886	307.497	278.669	0.0901074
9	226.566	262.484	308.973	275.882	0.0900641
10	225.18	265.109	310.503	273.123	0.0900285
11	223.829	267.76	312.074	270.392	0.0899416
12	222.562	270.438	313.764	267.688	0.0901746
13	221.068	273.142	315.098	265.011	0.08839
14	221.292	275.874	319.043	262.361	0.0992363
15	211.061	278.633	307.038	259.738	0.0282204

Table 5: labor tax is 0.35%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	242.014	242.4	301.848	298.98	0.162833
2	242.845	244.824	300.36	295.99	0.158365
3	243.48	247.272	299.029	293.03	0.159366
4	244.188	249.745	297.678	290.1	0.159425
5	244.923	252.242	296.338	287.199	0.159648
6	245.694	254.765	295.002	284.327	0.159845
7	246.501	257.312	293.673	281.484	0.160049
8	247.343	259.886	292.348	278.669	0.160252
9	248.221	262.484	291.029	275.882	0.160457
10	249.136	265.109	289.716	273.123	0.160667
11	250.086	267.76	288.402	270.392	0.160856
12	251.093	270.438	287.124	267.688	0.161178
13	252.021	273.142	285.669	265.011	0.16074
14	253.674	275.874	285.27	262.361	0.164668
15	251.4	278.633	278.8	259.738	0.143288

Table 6: labor tax is 0.55%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	238.902	242.4	298.611	298.98	0.231771
2	242.246	244.824	294.888	295.99	0.226252
3	245.43	247.272	291.303	293.03	0.22786
4	248.803	249.745	287.629	290.1	0.228158
5	252.303	252.242	283.906	287.199	0.228697
6	255.95	254.765	280.124	284.327	0.229193
7	259.744	257.312	276.282	281.484	0.229696
8	263.691	259.886	272.378	278.669	0.230196
9	267.796	262.484	268.408	275.882	0.230697
10	272.064	265.109	264.37	273.123	0.231192
11	276.504	267.76	260.268	270.392	0.231704
12	281.099	270.438	256.064	267.688	0.232113
13	285.973	273.142	251.934	265.011	0.233051
14	290.507	275.874	246.919	262.361	0.231178
15	298.046	278.633	246.148	259.738	0.244015

9 Appendix C

Proof of 2.1

$$B = \begin{bmatrix} \lambda_0 & \lambda_1 \\ 1 & 0 \end{bmatrix}, A = \begin{bmatrix} \alpha_1 & \alpha_2 \\ \beta_1 & \beta_2 \end{bmatrix} \tag{8}$$

$$AB = \begin{bmatrix} \alpha_1\lambda_0 + \alpha_2 & \alpha_1\lambda_1 \\ \beta_1\lambda_0 + \beta_2 & \beta_1\lambda_1 \end{bmatrix} \tag{9}$$

$$\begin{bmatrix} B, AB \end{bmatrix} = \begin{bmatrix} \lambda_0 & \lambda_1 & \alpha_1\lambda_0 + \alpha_2 & \alpha_1\lambda_1 \\ 1 & 0 & \beta_1\lambda_0 + \beta_2 & \beta_1\lambda_1 \end{bmatrix} \xrightarrow{R_1 \to R_1(-\frac{1}{\lambda_0})} \tag{10}$$

$$\begin{bmatrix} -1 & -\frac{\lambda_1}{\lambda_0} & -\frac{\alpha_1\lambda_0+\alpha_2}{\lambda_0} & -\frac{\alpha_1\lambda_1}{\lambda_0} \\ 1 & 0 & \beta_1\lambda_0 + \beta_2 & \beta_1\lambda_1 \end{bmatrix} \xrightarrow{R_2 \to R_1 + R_2} \tag{11}$$

$$\begin{bmatrix} -1 & -\frac{\lambda_1}{\lambda_0} & -\frac{\alpha_1\lambda_0+\alpha_2}{\lambda_0} & -\frac{\alpha_1\lambda_1}{\lambda_0} \\ 0 & -\frac{\lambda_1}{\lambda_0} & -\frac{\alpha_1\lambda_0+\alpha_2}{\lambda_0} + \beta_1\lambda_0 + \beta_2 & -\frac{\alpha_1\lambda_1}{\lambda_0} + \beta_1\lambda_1 \end{bmatrix} \xrightarrow{R_1 \to R_2 - R_1} \tag{12}$$

$$\begin{bmatrix} 1 & 0 & \beta_1\lambda_0\beta_2 & \beta_1\lambda_1 \\ 0 & -\frac{\lambda_1}{\lambda_0} & -\frac{\alpha_1\lambda_0+\alpha_2}{\lambda_0} + \beta_1\lambda_0 + \beta_2 & -\frac{\alpha_1\lambda_1}{\lambda_0} + \beta_1\lambda_1 \end{bmatrix} \xrightarrow{R_2 \to R_2(-\frac{\lambda_0}{\lambda_1})} \tag{13}$$

$$\begin{bmatrix} 1 & 0 & \beta_1\lambda_0\beta_2 & \beta_1\lambda_1 \\ 0 & 1 & \frac{\alpha_1\lambda_0}{\lambda_1} + \frac{\alpha_2}{\lambda_1} - \frac{\beta_1\lambda_0^2}{\lambda_1} - \frac{\beta_2\lambda_0}{\lambda_1} & \alpha_1 - \beta_1\lambda_0 \end{bmatrix} \tag{14}$$

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