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A Post-Keynesian Model for Controlling GDP and Debt

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Abstract

The Great Recessionary period that followed the 2008 crisis has severely impacted the European Union's debt-to-GDP dynamics. Austerity measures, implemented in highly indebted economies to restore fiscal credibility and promote long-term growth, failed to stimulate GDP and stabilize debt. The article offers a set of fiscal policy rules able to provide GDP growth and debt reduction using a linear, time-lagged, discrete macroeconomic post-Keynesian model. The algebraic methods with appropriate symbolic algorithms, through the feedback control techniques developed below, allow us to find a path for the GDP and debt desired targets to be met. Consequently, this study argues that expansionary fiscal policy can be a powerful tool for stimulating the economy in association with specific tax regimes.

JEL Classification: E00, E62, E12

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I. Introduction

Fiscal policy is a thorny issue in the economics literature. In particular, its effectiveness in managing the relationship between GDP and debt has been thoroughly questioned due to its limited capacity to produce long-term economic growth and its inability to meet budget requirements (Bernanke, 2004). The mainstream approach highlights fiscal policy's inability to simultaneously bring GDP growth and debt reduction due to its high budgetary costs of affording expansionary government spending (Blanchard, 2010). On the other hand, economists with more critical views maintain that fiscal policy still plays an active role in stimulating the economy. Following Keynes and Kalecki, post-Keynesian scholars argue in favour of an expansionary fiscal policy that would vitally stimulate the economy regarding the key sectors, guide expectations and restore economic confidence (Arestis, 2011; Hein, 2018).

The popularity of fiscal policy as a tool to permanently stimulate the economy declined with the demise of Keynesianism at the end of the 1970s, and similarly, the role of the government as actively intervening in the economy. Changes that immediately followed this period, including financial liberalization, privatizations and deregulation, have also made expansionary fiscal policy considered inefficient. Namely, it was accused of leading to rigidities in the capital market. In the 90’s and the early 00’s, fiscal consolidation was considered the primary tool for stimulating the economy (Streeck, 2014). According to mainstream theory, cuts in government expenditure are expected to promote sustained growth since efficiency is supposed to be achieved under a framework of minimum government role. (Giavazzi & Pagano, 1990; Bertola & Drazen, 1993; Alesina & Perotti 1995; Alesina et al., 1998; Ardagna, 2004).

The aftermath of the 2008 recession showed that fiscal consolidation, used as the main instrument to control the impact of the crisis, failed to provide the declared purposes of stability and growth. Over the last decades, the effect of fiscal policy on growth has re-emerged, as the expanding interest in fiscal multiplier effects suggests (Blanchard & Leigh, 2013; Gechert, 2015).

On the other hand, many post-Keynesian models focus on the active role of fiscal policy, arguing that fiscal policy interventions can stimulate the economy (Hein & Stockhammer,

2012; Allain, 2015; Tavani & Zamparelli, 2017; Ko, 2018). In an economy that sets policy targets for its economic performance with expansionary fiscal policy, the desired path to approach them is highly important (Haavelmo, 1945).

Mathematical control theory literature has produced a tool for tracking an economic system, whereas feedback control has been utilized to find a desired path for the policy targets. Important results have been derived from this literature (e.g., Kendrick, 1993; Kaas, 1998; Kotsios & Leventidis, 2004; Athanasiou & Kotsios, 2008).

A closed-loop feedback control allows a system to correct for a lack of complete knowledge about intrinsic system dynamics. Feedback alters the input as the error difference between the system's output and the desired target output. By feeding back the error into the system, we can modulate the process to move in a direction that reduces error (Frank, 2018).

This approach has the advantage that it ensures that the predefined policy targets will be followed because of the feedback control, and the solution for the policy problems can be a vector of fiscal policy rules. From an economic policy point of view, this technique allows us to choose the optimal path, considering a policy choice depending on the problem at hand. Moreover, the solution technique is parameterized, and thus, it allows for proper symbolic algorithms to be developed. An additional advantage of this technique is that it helps shorten the policy lags. The economy will move to the desired trajectory since the implementation of the fiscal policy rules, as the time path of the instruments is designed so there is an immediate adjustment of the system (Kostarakos & Kotsios, 2018). Therefore, this methodology allows policymakers to intervene more frequently, which could lead to a smoother transition path for the economy (Kendrick & Amman, 2014).

The response to the 2008 crisis had two main pillars regarding fiscal policy, influenced by the neoclassical model: First, expansionary fiscal consolidation, forcing countries to reach a balanced budget quickly; second, internal wage devaluation to increase competitiveness. Both, especially the labour market reformation, devastated domestic consumption, a main driver of growth (Ruiz, 2023).

This article aims to address the issue of designing fiscal policy rules to achieve GDP growth and debt reduction, arguing that an alternative path for growth exists.

For that, we propose a linear, deterministic variant of a post-Keynesian model, a variant also proposed by Kalecki (1971). In Kaleckian models, society is divided between two classes: capitalists and workers. The former owns the means of production, and the latter are remunerated for providing their labour time. There is a fundamental separation between two types of consumption: capitalists' and workers'. Thus, there are two separate forms of taxation: labour and capital.

Our aim is to develop a system of taxation to account for the reduction of debt while simultaneously being of service to GDP growth. Taxation is here considered a tool for financing government expenditures, causing a favourable chain reaction to GDP growth while promoting sustainability. The method presented here falls into the mathematical control theory. We provide a symbolic algorithmic analysis and combine it with a post-Keynesian model to determine the proper level of government expenditure that would lead to economic stimulus. This symbolic algorithmic method ensures we find a sustainable path that meets the required policy targets for debt control and GDP growth. We present and compare our findings with a Samuelson model (Samuelson, 1939).

Our results indicate that for an economy like Greece in early 2020, which faces a high debt-to-GDP ratio, implementing expansionary fiscal policy leads to positive GDP growth rates and debt reduction. In the second section, we present the economic theory debate on the effects of fiscal policy on the macroeconomy. In the third section, we present the model. In the fourth section, we state the problem and the solution technique. Section five presents the relevant algorithms. In section six, we provide the counterfactual policy experiments. Lastly, section seven offers the concluding remarks.

II. Fiscal Policy from a Post-Keynesian Perspective

Mainstream Literature

The 1980s represented the nail in the coffin for the usage of fiscal policy. The oil shocks, stagflation and the failure of leading economists to provide meaningful answers to the crisis led to a paradigmatic shift in economic theory. Supported by the mantra of liberalization and shrinking of the state, the economic policy also experienced an important turn: from fiscal to monetary, controlling public debt and ensuring a balanced budget would be the key to a

stable path. Under the establishment of neoliberalism, seminal papers arguing that fiscal consolidation could lead the economy to overcome the emerging debt crisis began to emerge, and thus, the scientific consensus went from expansionary to fiscal consolidation (Feldstein, 1982; Giavazzi & Pagano, 1990, *inter alia*).

In 1982, Feldstein argued that the expectations regarding fiscal policy have a significant impact on its effects on the economy. He claimed that the former could be expansionary if the government expenditure cuts are realized as future tax cuts. In the same context, Blanchard (1990) and Bertola and Drazen (1993) support the idea that the public considers any government expenditure hike as a future tax increase. Thus, it will have a negative impact on public consumption and investment. A milestone of this theory is the work of Gavvazzi and Pagano (1990), who empirically studied the effects of fiscal policy implemented in Denmark and Ireland during the 80s. Their findings indicate that the rise in consumption was due to decreased government expenditures due to the Ricardian equivalence (Barro, 1974). Thus, they argue that fiscal consolidation could be expansionary.

The 1990s saw the emergence of the Washington Consensus and the European Stability Pact, which embodied these core fiscal control principles and began to be implemented in regions facing debt crises, such as Latin America and Sub-Saharan Africa. Expansionary Fiscal Consolidation (EFC) aims for a sustainable debt-to-GDP relationship with government expenditure cuts as its primary tool. According to the Neoclassical theory, markets are efficient and work better if left alone, while the government's role should be limited only to distributing. Additionally, the EFC argues that tax hikes can be recessionary as they imply a much larger loss of output compared to what could have resulted through consolidations relying on reductions in government spending. (e.g., Guarjado et al., 2014; Alesina et al., 2018).

Alesina & Perotti (1995) and Alesina et al. (1998) studied the fiscal adjustments that took place in many countries over these decades and argue that when fiscal consolidation is implemented targeting government expenditure cuts, it affects the debt-to-GDP relationship positively and can generate growth. This view is consistent with the preferences related to the size and activity of the state from the neoclassical point of view. According to Calcagno (2012), those who support an active role of the government in income redistribution will opt

for tax increases, especially in progressive taxation, while those with opposing preferences will support cuts in public expenditure.

In the first years of the 2008 Recession, Alesina et al. (2010) and Guarjado et al. (2014) – among many others – reopened the dialogue regarding fiscal consolidation. Their main argument maintains that the governments postpone fiscal adjustments because they are considered recessionary. However, their studies suggest that fiscal consolidation is linked with growth without having social costs.

Notably, under the Stability and Growth Pact (SGP) agreement, a state's budget deficit cannot exceed 3% of GDP, and national debt cannot surpass 60% of GDP. Following the amended SGP, an excessive deficit procedure is triggered by the deficit criterion or the debt criterion: the former is that a general government deficit is considered to be excessive if it is higher than the reference value of 3% of GDP at market prices, and the latter that debt is higher than 60% of GDP and the annual debt reduction target of one-twentieth of the debt over the 60% threshold has not been achieved over the last three years. The debt criterion is only concerned with reducing annual debt without including any targets for GDP growth.

Post-Keynesian literature

Even though expansionary fiscal policy theory was side-lined during the neoliberal era, multiple authors followed the post-Keynesian literature, arguing that a fiscal policy mechanism combined with targeting income redistribution towards wages can be vital for growth.

The post-Keynesian literature suggests that an increase in government spending (to put it differently, an increase in the budget deficit) will lead to a direct (through government's purchases) and indirect (through higher workers' spending) increase in total effective demand, which will give rise to greater output, profits and wages (Ciccone, 2013).

Many scholars during the 80s claimed that redistribution of income towards wages could positively impact the economy. If the desired accumulation (investment demand) is an increasing function of both realized profits and the utilization rate, it may result in a higher

rate of capital accumulation (Bhaduri & Marglin, 1990; Blecker, 1989; Dutt, 1984; Rowthorn, 1981; Taylor, 1985).

Over the past 20 years, multiple authors proposed models that focus on expansionary fiscal policy. The works of Hein and Stockhammer (2012), Allain (2015), Tavani and Zamparelli (2017), and Ko (2018) claim that the economy can be stimulated through an appropriate mix of fiscal policy interventions.

More specifically, Tavani and Zamparelli (2017) developed a demand-driven growth and distribution model and argued that long-run growth is wage-led, regardless of the level of government debt. Furthermore, they claim that government spending can stimulate the economy in the long run. In the same context, Allain (2015) presents a Kaleckian model with autonomous public expenditure and shows that growth is affected positively by government spending. Moreover, he argues that public expenditures can stabilize economic growth and that a rise in the profit share induces negative effects on economic activity.

Nah and Lavoie (2017) combined a neo-Kaleckian model with a sort of Sraffian super-multiplier mechanism and showed that a decrease in the propensity to consume or an increase in the profit share could have a negative impact on the average rates of capital accumulation and economic growth. Again, there is a direct negative effect on growth when labour's earnings are kept at low levels.

Namely, Hein (2018) focuses on the deficit, debt, and distributional effects of an exogenous or autonomous growth rate of government expenditures, arguing that the latter can stimulate growth without triggering unsustainable debt dynamics if government expenditures are both stronger than the relative rentiers' propensity to consume out of wealth and higher than the exogenous rate of interest on government debt. So, the economy is led towards a higher long-run equilibrium government expenditures– and thus primary deficit–capital ratio.

Commendatore and Pinto (2011) propose a neo-Kaleckian model to understand the consequences of changes in the composition of public expenditure, arguing that an increase in the size of the public sector positively affects growth. Dutt (2013) and Palley (2013) claim that private and public investment are complementary, arguing that public investment will have positive effects on private investment, supporting the "crowding-in" assumption.

The main distinctive feature of Kaleckian's theory of taxation is the distinction between taxes on labour and capital, as well as their implications for output determinations. Kalecki (1971) proposed that to maintain a high level of employment, the government should interfere with deficit spending, which would induce a fiscal deficit. Suppose workers have zero propensity to save, meaning they consume all their income. In that case, taxation needed to service the government debt shall fall upon wealthy individuals (capitalists). However, the money will be returned to them in proportion to their holdings of government bonds (Toporowski, 2020).

Capitalist investments and consumption remained unaltered immediately after introducing the new income tax because of the fiscal policy response lags (Asada & Yoshida, 2001). Thus, employment increases and gross profits rise by the amount of the increment of taxation. Various scholars believe progressive taxation can stimulate the economy (Laramie, 1991; You & Dutt, 1996; Blecker, 2002; Palley, 2014). Specifically, You and Dutt (1996), after studying a range of different tax rates between labour and capital, come to conclude that income distribution towards labour is necessary for growth, and it can be achieved if a worker’s after-tax income rises faster than interest payments on debt. Nikolaidi et al. (2020) examine the effects of fiscal policies on growth with a post-Kaleckian theoretical model and find that a rise in the labour share leads to an increase in growth. Moreover, they argue that a redistributive tax policy leads to an increase in GDP. These results fall into the post-Keynesian literature, where taxation can be a tool for financing government expenditures, which can cause a chain reaction to GDP growth.

Ko (2018) examined the effects of an increase in government debt and a rise in income tax rates on the economy. He argues that raising capitalist taxation can promote growth by positively affecting capacity utilization. Moreover, regarding the government debt, he argues that expanded budget deficits can lead to economic growth in the long run. However, a high debt burden can decrease the aggregate demand since government borrowing must increase more rapidly than income to ensure a higher budget deficit ratio.

Numerous scholars argue that government spending can stimulate productivity and create fiscal space in the long run by stimulating income growth and expanding the tax base (Seguino, 2012).

III. The Model

There has been an increase in the dissemination of Kaleckian models in economics literature, particularly in post-Keynesian literature. Their main focus is to examine the long-run and short-run dynamics of the policy implications, mostly focusing on income distribution and government expenditures (Lavoie, 1995; Allain, 2015; Hein, 2018). The most common methodology is through a dynamic analysis to find the multiplier effect of government intervention on capacity utilization. This approach provides useful implications for macroeconomic policy when tackling economic instability and stimulating GDP growth.

Rather than adopting a dynamic analysis, this article introduces a technique that falls into the Mathematical Control Theory (Kendrick, 1993; Kaas, 1998; Kotsios & Leventidis, 2004; Athanasiou & Kotsios, 2008; Kostarakos & Kotsios, 2018). This technique of policy design (min-loss function) was used extensively until the 1970s but was side-lined due to Lucas' critique, which argues that the impact of fiscal policy has no effect as people rationally adjust their expectations and behaviour based on how they understand it. Reinstating this approach allows us to find the optimal policy path for stimulating GDP while simultaneously having a sustainable debt through government expenditures and taxation.

Following You and Dutt (1996), we assume the government finances its budget deficit by borrowing. In addition, Ko (2018) assumes that the economic system is closed and that workers have zero propensity to save, while the capitalists save a constant fraction of their disposable income and earn interest revenue by purchasing government bonds. Also, according to the neo-Kaleckian models (Dutt, 1990; Taylor, 1991), a firm's profit margin is considered to be given to the economy and not an endogenous variable. The latter means that for a given level of technology, the real wage level is also constant; it is not considered an endogenous variable.

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 income distribution, the workers' consumption induced by capitalist expenditure will remain constant if the latter does not change. Accordingly, the increase in government spending (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 (which remunerates labour), and capitalists earn a profit and an interest income (which remunerates capital).

Adopting a modified version of a post-Keynesian model is based on two reasons. First, its tractability allows us to treat government expenditures as an exogenous variable to approach the predetermined targets for GDP and debt. Secondly, it divides workers and capitalists through taxation. In this model, following the Kaleckian literature, Lavoie (1995), You and Dutt (1996), the economy is separated between two classes, workers and capitalists and the overall private consumption is split between them. A modification we made is to assume that the decision regarding government expenditures in period t affects the level of GDP in period $t+i$; that is, there is a delay in realising the effects of changes in government expenditures on GDP levels. We also assume that price level is not affected by tax hikes, as capitalists internalise the cost of taxation. This is realised through their after-tax profits, but the money will be returned to them in proportion to their holdings of government bonds.

We opt for a linear, deterministic model of the macroeconomy, which will allow us to assess the proposed policy plan's effects thoroughly. More specifically, we use a variant of a post-Keynesian model coupled with the government budget constraint.

Assuming a closed economy, the income identity is:

$$Y(t) = C(t) + I(t) + \lambda 0 G(t) + \lambda 1 G(t-1) \quad (1)$$

In this model, following Kostarakos and Kotsios (2018) and Kendrick and Shoukry (2014), we argue that the government's decision to spend in period t is not immediately realized into outlays; rather, actual disbursement of the funds is spread over the following periods. Thus, the parameters $\lambda 0$, $\lambda 1$ indicate the percentage of the government's decision to spend in period t that is disbursed in period $t+i$, $(i = 1,..,15)$, with $\lambda 0 + \lambda 1. = 1,\ 0 < \lambda 0,\ \lambda 1$. This 'spending' mechanism is used to incorporate the well-known lags of fiscal policy, 'inside' and 'outside' lag. The former refers to the time elapsed until the downturn of the economy is recognized and the time necessary for the policymaker to formulate a response. Outside lag refers to the time until the policy action undertaken affects the economy.

Regarding the behavioural equations, we apply Ko (2018) to assume that consumption is divided between workers and capitalists:

$$C(t) = CL(t) + CC(t) \tag{2}$$

Where,

$$CL(t) = (1 - \tau l)L(t), \tag{3}$$

$$CC(t) = (1 - s)(1 - \tau c)(WC(t) + rB(t - 1)) \tag{4}$$

So,

$$C(t) = (1 - \tau l)L(t) + (1 - s)(1 - \tau c)(WC(t) + rB(t - 1)) \tag{5}$$

Where C is consumption, L is labour income, Wc is the capitalist's income, τl is the tax rate for wage income, τc is the tax rate for capital income, $s \in (0,1)$ is the 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 who purchase government bonds. This represents the capitalists' yield from an additional interest income resulting from a rise in interest rates or government debt, which increases their consumption expenditure.

Workers' and capitalists' income are assumed to be extracted by the labour and capitalist's share, respectively, that is:

$$L(t) = gY(t - 1) \tag{6}$$

$$WC(t) = hY(t - 1) \tag{7}$$

Where g is the labour and h denotes the capital share, respectively.

Regarding investment, we assume that it depends on the investment rate, k, and the last period's GDP, that is:

$$I(t) = kY(t - 1) \tag{8}$$

The government budget constraint follows the standard form, with a modification we implemented, as taxation is divided between capitalists and workers:

$$B(t) = B(t-1) + rB(t-1) + G(t) - TL(t) - TC(t) \quad (9)$$

Where $B(t)$ denotes debt outstanding, r is the interest rate, and

$$TL(t) = \tau lL(t), TC(t) = \tau cWC(t) \quad (10)$$

Where $Tl(t)$ and $Tc(t)$ are the revenues from labour and capital taxation, respectively.

By working on these relations, we end up with a system of two equations of one input, $G(t)$ and two outputs, $Y(t)$, $B(t)$

$$Y(t) = (h(s-1)\tau c + g(-\tau l) + g - hs + h + k)Y(t-1) + r(s-1)B(t-1)(\tau c - 1) + \lambda 0 G(t) + \lambda 1 G(t-1) \quad (11)$$

$$B(t) = (r+1)B(t-1) - (h\tau l + g\tau c)Y(t-1) + G(t) \quad (12)$$

After the necessary substitutions and some algebra among Equations 11 and 12, we end up with the following:

$$Y(t) = \alpha 1 Y(t-1) + \alpha 2 B(t-1) + G(t)\lambda 0 + \lambda 1 G(t-1) \quad (13)$$

$$B(t) = \beta 1 Y(t-1) + \beta 2 B(t-1) + G(t) \quad (14)$$

Were,

$$\alpha 1 = (h(s-1)\tau c + g(-\tau c) + g - hs + h + k),$$
$$\alpha 2 = r(s-1)(\tau c - 1),$$
$$\beta 1 = (h\tau l + g\tau c),$$
$$\beta 2 = (r+1)$$

This is the input-output form of the model, with $G(t)$ being the input and $Y(t)$ and $B(t)$ being the outputs. This discrete system can be rewritten more compactly by utilizing the state-space form. To write (13) and (14) in a state-space form, we introduce the state vector:

$$\vec{x}(\mathrm{t})=\begin{bmatrix}Y(t)\\B(t)\end{bmatrix},\quad \vec{u}(\mathrm{t})=\begin{bmatrix}G(t)\\G(t-1)\end{bmatrix} \tag{15}$$

and thus

$$\vec{x}(\mathrm{t})=\boldsymbol{A}\vec{x}(t-1)+\mathbf{F}\vec{u}(\mathrm{t}) \tag{16}$$

$$\vec{x}(t)=\boldsymbol{A}\vec{x}(t-1)+\begin{bmatrix}\lambda o & \lambda 1\\1 & 0\end{bmatrix}\begin{bmatrix}G(t)\\G(t-1)\end{bmatrix} \tag{17}$$

From here, it can be easily proved that

$$\mathbf{W}=[\boldsymbol{B},\boldsymbol{AB}] \tag{18}$$

has full row rank that is rank $\boldsymbol{W}=2$. Hence, system (17) is controllable (Astrom & Murray, 2009).

IV. Formulation of the Problem

As mentioned earlier, the SGP affects highly indebted countries, targeting their debt reduction and long-run fiscal sustainability. We suggest that debt reduction is necessary. Nevertheless, it should be followed by GDP growth. Certain fiscal policy rules should be applied to achieve GDP growth and debt reduction. For example, if there are predefined targets for GDP and debt-to-GDP ratio in a timeline for each period a particular economy must meet, it becomes a tracking problem. In particular, it amounts to finding a policy so the system approaches the requested output values.

Our analysis must consider a policy choice, as there has to be a criterion for evaluating the desired path for the targets to be met. Thus, we incorporate the flexible targets theory, developed by Theil (1956) (i.e., $Y*(t), B*(t)$, should be approached as closely as possible, but not necessarily attained exactly), which will allow us to discriminate between paths that are either feasible or 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 the above, we introduce the equation of total error, which will serve us as the objective function. The following equation holds for solving a tracking problem in which the tracking error is minimized:

$$min \sum_{i=1}^{n}((Y[t] - Y*[t])^2 + (B[t] - B*[t])^2 \quad (19)$$

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. $Y(t)$ and $B(t)$ are our model outputs for GDP and debt.

Equation (19) is the least squares of the GDP and debt over the predefined targets we have already set, assigned with equal weights to GDP and debt. In particular, it is the sum of all the errors for all the periods under examination, and we are searching for $G(0)$, $G(1)$,...,$G(t)$ that minimizes this sum over $G(t)$ for each period t. The problem now breaks down into two parts. First, we will choose the ideal paths, $Y*(t)$ and $B*(t)$, and then the choice of policies that will lead us towards them. This results in a greater degree of flexibility in planning.

The applied method builds on an objective function that will confirm whether the system approaches the targets or not and, in addition, which fiscal policy rules are needed for the targets to be as close as possible. In particular, the method followed in this study is to minimize the cumulative error (i.e., the deviation of the actual values and the targets), which is our quadratic objective function, using the least squared method. We expand Equation (19) for various values of the time t, and then we must minimize it, concerning $G(0), G(1), \ldots, G(t)$. To achieve that, we use a symbolic algorithm, presented below.

V. The Algorithm

A recursive algorithmic procedure has been developed to assist us in solving the problem of designing an appropriate fiscal policy. The following steps are calculated to find the optimal government expenditures for each time step of the model.

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

Output: The desired levels of $G(t)$, $t = 0,..,n$, $(n = 1,..15)$

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

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

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

VI. Policy Simulations and Experiments

This section presents a set of policy experiments to examine the effects of the proposed methodology for designing fiscal policy. We develop scenarios to test the method under normal and extreme conditions. In case the results are normal and extreme, respectively, then the method is functioning well. First, it is assumed that the policymaker aims for a modest 1% annual GDP growth and an additional 1% decrease in the public's debt levels for 15 years. Our starting point for the levels of GDP and debt is based on their actual values for 2020. The target levels of GDP and debt are denoted by $Y*(t)$ and $B*(t)$, respectively. The parameters h, s, k, r, and g are assumed to be 0.4, 0.3, 0.2, 0.02, and 0.5, respectively, based on their average values of the EE-27 (Eurostat). In the first part, we present some extreme taxation scenarios, where the outputs for various values of tc and tl are examined to gain insight into taxation's effects on both social classes (capitalists and workers) through fiscal policy implementation. Specifically, the following figures present the outcomes of GDP and debt (denoted by Y and B) for different values of tc and tl, along with the government expenditures divided by the actual GDP. To provide some insight into the effectiveness of fiscal policy, two extreme scenarios for policymaking around different levels of labour and capital taxation are developed. The policy targets and starting points ($Y(0)$, $B(0)$) following the general logic of an SGP for a highly indebted country, though including a target for GDP as well as debt:

GDP growth 1%, Y(0)=200

Debt reduction 1%, $B(0) = 330$

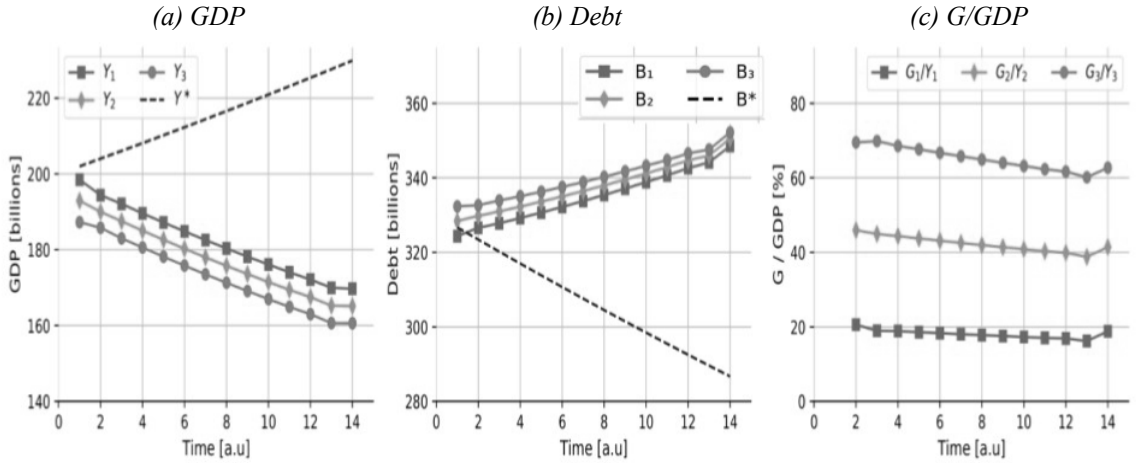
$Y*(t)$, $B*(t)$

Scenario 1: Capital Taxation is Constant, and Labour Taxation Varies.

The “low capital taxation”: Here, we assume that capital tax is fixed at 10% and present the debt and government expenditures as a percentage of GDP for three different values for labour tax: **(1)** labour tax is 17%, **(2)** labour tax is 45%, and **(3)** labour tax is 73%. The target values for GDP and debt, denoted by $Y*(t)$ and $B*(t)$, results for GDP respectively.

Appendices 1, 2, and 3 present the target values for GDP, debt, their targets, and government expenditures as a percentage of GDP over 15 periods (see Appendix). Figures 1a, 1b, and 1c present the time path for three different outcomes of GDP, debt and their targets, government expenditures over GDP, which are calculated under different specifications for the tc and tl and parameters. Table 1 shows the terminal values for GDP and debt when capital tax is constant at 10%

Figure 1: Temporal Trends: GDP, Debt, Target Values, and Government Expenditures as a Fraction of GDP



Source: Own Calculations.

Table 1: Terminal values for GDP and debt when capital tax is constant at 10%

Labour Tax	GDP	GDP Target	Debt	Debt Target
17%	169.712	229.895	348.575	286.686
45%	165.123	229.895	350.552	286.686
73%	160.619	229.895	352.194	286.686

Source: Own Calculations.

It is evident from Figures 1a, 1b and 1c that for the first scenario, where the capital tax is fixed at 10%, there is no path approaching the targets for GDP and debt. Table 1 presents the terminal values of GDP and debt after 15 periods, where we can see a huge decline between them and their targets. This happens since consumption plays a vital role in GDP. As workers consume all of their income, with high levels of labour taxation, disposable income decreases

sufficiently, and consumption becomes unable to bring growth. In addition, there is no point where government expenditures can affect actual GDP in approaching the targets as with these low levels of capital taxation, the government has vastly decreased its income, which is taxation, and thus, there are not enough funds for government expenditures.

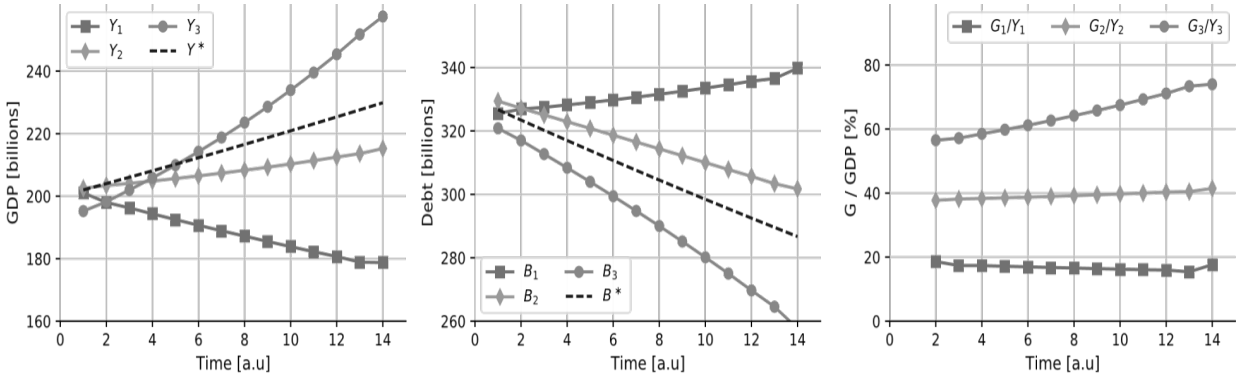
Scenario 2: Labour Taxation is Constant, and Capital Taxation Varies.

The "low labour taxation scenario" assumes that labour tax is fixed at 10% and capital tax takes three different values: **(1)** capital tax is 17%, **(2)** capital tax is 45%, and **(3)** capital tax is 73%.

In Appendices 4, 5, and 6, the target values for GDP, debt and their targets are presented, along with the government expenditures over GDP for a time length of 15 periods. Figures 2a, 2b, and 2c present the time path for three different GDP and debt outcomes and their targets, as well as government expenditures over GDP (calculated under different specifications for the tc and tl parameters; see 8). Table 2 shows the results for GDP and debt when the labour tax is constant at 10%.

Figure 2: Temporal Trends: GDP, Debt, Target Values, and Government Expenditures as a Fraction of GDP

(a) GDP *(b) Debt* *(c) G/GDP*



Source: Own Calculations.

Table 2: Results for GDP and debt when the labour tax is constant at 10%.

Capital Tax	GDP	Debt
17%	No path for convergence due to a low capital tax rate that does not lead to the level of revenues that could finance public expenditures for GDP creation.	No path for convergence due to the accumulation of deficit is straightforwardly converted into debt
45%	There exists a path for GDP growth due to a rise in government expenditures which are finance by capital tax	There exists a path for debt reduction as government's revenues from taxation exceed the government expenditures
73%	GDP growth overcomes the targets due to high levels of governments expenditures	Debt reduces vastly more than its target due to the high capital tax rates

Source: Own Calculations.

On the other hand, from the second scenario, it is observed that 2a, 2b and 2c, where labour tax is fixed at 10%, we are provided with different results. In cases 2 and 3, where capital taxation is set at 45% and 73%, there are paths of GDP growth along debt reduction. Both of those follow the targets' direction, but they do not converge. These results are compatible with the post-Keynesian literature since workers' incomes have increased due to lower taxation, and consumption stimulates GDP. Moreover, the government's expenditures decrease in national debt, as the not cause in government's earnings from taxation overcome the expenditures. As for capitalists, even in high levels of capital taxation, their holdings of government bonds will return their money since the GDP has grown or even increased their income. Hence, public investment positively affects private investment, according to the "crowding-in" assumption (Palley, 2013).

Another critical issue is that as taxation rises, government spending increases as a percentage of GDP. That is because higher taxation leads to lower consumption, which is vital for GDP growth. So, government expenditures fill the gap generated in the economy. Still, in high levels of taxation (i.e., 73%), G/GDP reach some unrealistically high limits, examined only for the sake of the exercise.

Comparing with a "Standard" Model

In what follows, we compare the results of the post-Keynesian model with a linear, deterministic variant of the standard Multiplier-Accelerator model introduced by Samuelson (1939). For the comparison, we use the simple form of a Samuelson model, applying the same values for the targets and the parameters.

The main difference between these two models is the consumption function, where the classification of the economy is not included, and thus, taxation is not divided between capital and labour.

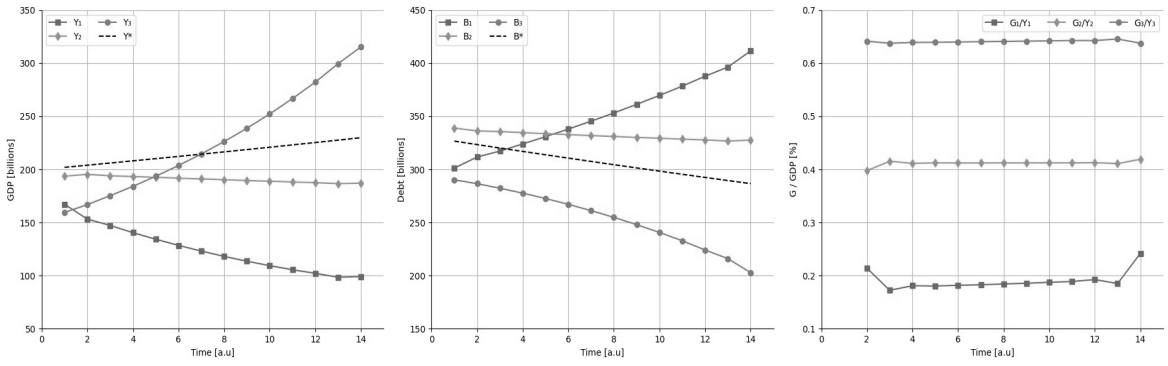
$$Y(t) = C(t) + I(t) + \lambda 0 G(t) + \lambda 1 G(t-1) \tag{20}$$

$$B(t) = B(t-1) + rB(t-1) + G(t) - T(t) \tag{21}$$

Figures 3a, 3b, and 3c 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 parameter (see Appendix): **(1)** taxation is 17%, **(2)** taxation is 45%, and **(3)** taxation is 73%.

Figure 3: Temporal Trends: GDP, Debt, Target Values, and Government Expenditures as a Fraction of GDP

(a) GDP *(b) Debt* *(c) G/GDP*



Source: Own Calculations.

As we observe from Figures 3a and 3b, the targets can be approached for the second and the third cases (i.e., when taxation is 45% and 73%). For this to happen, government expenditures in need are, for the second case, around 40% and for the third, around 63% of GDP. This makes sense, as the government's earnings are higher with these taxation levels, and thus, the government can spend its income to achieve GDP growth and debt reduction. Implementing fiscal policy rules extracted by the Samuelson model keeps taxation at high levels and provides the economy with significant government expenditures. It is evident that, in both models, government expenditures are vital for GDP growth and debt reduction. An important issue is that in contrast with the Samuelson model, the one we implemented (i.e., post-Keynesian) divides taxation between the two classes. Thus, the policymaker could have an overall view on which specific form of taxation must occur. Moreover, government expenditures in our model are significantly more feasible for an economy than Samuelson's model when labour taxation is kept at low levels while the taxation of capital is at high values.

VII. Discussion and Policy Recommendations

Summary Results

The results presented above are compatible with the post-Keynesian literature, as expansionary fiscal policy and income redistribution towards wages can cause a chain reaction towards stimulating GDP. Inequality has a negative effect on demand growth as those with higher incomes consume a smaller share, causing a drag on the economy. Moreover, a decrease in workers' income through high levels of taxation, while capitalists are kept at low levels, creates a recede in GDP and an increase in public debt. Taxation and government expenditures can have a positive impact on GDP and debt. More specifically, income redistribution towards wages increases workers' final demand and can stimulate consumption as workers' propensity to consume is high, meaning they consume all their income. This rise in their income affects GDP positively, while capitalists increase their profits from their holdings of government bonds, which rise as GDP grows. Furthermore, the government's interference through fiscal deficits does not accumulate debt since its earnings from taxation seem to overcome its expenses. This means that public debt is also serviced, and under these policy rules, it declines annually. On the other hand, fiscal consolidation has a severe negative impact on GDP. Government spending is commonly considered a

percentage of GDP when analysing a country. However, when nominal GDP diminishes, social expenditures can be relatively low and should be treated carefully when analysed in relative terms.

Methodological Contribution

The contribution of the methodology introduced in this paper is that it provides the policymaker with a set of fiscal policy rules that can stimulate the economy. Depending on the GDP and debt targets, we construct a vector of policy implications that allows the policymaker to choose the optimal mix of taxes to achieve them. It is important that government expenditures and taxation can be manipulated efficiently with the feedback control method and adjusted depending on the problem at hand. This allows us to simulate the model with different GDP and debt targets and utilize more criteria for developing the optimal paths. Moreover, this method ensures an immediate adjustment to the system. Hence, there are no delays in the realization of the expansionary fiscal policy, resulting in obtaining important insights into the trajectory of each policy rule.

Policy Implications and Considerations

Specifically, regarding the policy implications, the state's role is vital and should be reconsidered. Aside from the ethical standpoint against inequality, allocating resources to support lower-income groups is also crucial for growth. It is obvious that fiscal consolidation and, specifically, government spending cuts are unable to have a positive impact on the economy (Missos et al., 2024). To achieve the annual growth targets along with annual debt decrease, decision-makers should focus on government spending to be around 40% of GDP and keep labour taxation low at 10%. In addition, according to Eurostat, annual government expenditures for social expenditures, education, health, and economic affairs amount to close to 40% of GDP for countries in the Euro area. Government expenditures do not negatively affect debt dynamics as the fiscal deficits do not seem to cause debt accumulation, as long as the government's earnings are higher than the government's expenses. Because of the absence of fiscal policy lags, capitalists don't lose profits as the rise in workers' effective demand increases their investment. As far as debt management is concerned, taxes on capitalists and profits should not be excluded. Instead, it can act as a tool for redistributing the income of the wealthy towards wages to ensure the fiscal deficits are financed.

Future Research and Extensions of the Model

The results presented in this research are based on a simple post-Keynesian model confined to fiscal policy. Regarding the model, it has the advantage that it can be manipulated analytically, and thus, it could be further expanded. More specifically, as mentioned before, the profit margin of firms is considered given for the economy as a whole, which means that it was an exogenous variable as exploring them was beyond the purpose of this study. Moreover, these results and policy implications are applied in a highly indebted economy with annual GDP growth and debt reduction targets. Hence, the initial conditions must be considered during the simulation process. We are currently working on another technique from the mathematical control theory (adaptive control), which will allow us to model endogenous variables. This will enable us to emphasize the future effects of the current policy actions. Furthermore, regarding the dynamics of the economy, assuming a closed economy allows the implementation of fiscal policy to have an immediate adjustment on the system. When dealing with an open economy, there will be bigger fiscal policy lags, and a method is needed to shorten them. Moreover, there is space to explore how much income should be allocated towards workers and the implications of such redistribution on GDP and debt regarding their respective targets.

VIII. Concluding Remarks

This paper presents a computational approach based on a post-Keynesian model developed for fiscal policy design based on algorithmic open-loop control methods. The results show that fiscal policy may affect the economy, simultaneously stimulating GDP growth and achieving debt reduction. Fiscal policy tools such as taxation and government expenditures can become efficient instruments for the policymaker. There is no evidence suggesting that the required level of government expenditures for boosting the GDP upwards has to overreach. This provides evidence against the mainstream narrative that expansionary fiscal policy can only have a negative impact on the debt-to-GDP ratio. On the contrary, fiscal policy is of high importance for the forthcoming years, as it is a powerful tool for bringing growth along a path of debt reduction, especially for countries which suffer from a high accumulation of outstanding debt.

In this paper, we have developed a modified version of a time-lagged post-Keynesian model, including an equation referring to the evolution of debt where we found fiscal policy rules based on taxation and government expenditures. To achieve the predefined targets for GDP and debt, fiscal policy must be implemented through capital tax hikes and a rise in government expenditures. While labour taxation is kept at low levels and capital taxation fluctuates above 40%, the economy approaches these targets. The outcomes indicate that taxation on capitalists should be higher than on workers. We have also adopted an algorithmic methodology based on computational feedback control methods. Using this method, we have shown that expansionary fiscal policy can lead to GDP growth.

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Appendices

Appendix 1. Results for GDP and Debt when Labor tax is 17%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	198.472	202.0	324.335	326.7	12.7346
2	194.391	204.02	326.596	323.433	20.5834
3	192.096	206.06	327.785	320.199	18.9561
4	189.585	208.121	329.216	316.997	18.8871
5	187.185	210.202	330.674	313.827	18.5718
6	184.841	212.304	332.194	310.688	18.3052
7	182.562	214.427	333.772	307.582	18.0391
8	180.345	216.571	335.408	304.506	17.7812
9	178.191	218.737	337.103	301.461	17.5298
10	176.099	220.924	338.859	298.446	17.2877
11	174.061	223.134	340.662	295.462	17.0382
12	172.133	225.365	342.601	292.507	16.8833
13	169.96	227.619	344.135	289.582	16.1984
14	169.712	229.895	348.575	286.686	18.8023

Source: Made by the authors

Appendix 2. Results for GDP and Debt when Labor tax is 45%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	192.928	202.0	328.414	326.7	44.8136
2	189.998	204.02	329.796	323.433	45.94
3	187.523	206.06	330.981	320.199	44.9381
4	185.036	208.121	332.271	316.997	44.3642
5	182.626	210.202	333.609	313.827	43.7272
6	180.276	212.304	335.006	310.688	43.1211
7	177.987	214.427	336.461	307.582	42.5277
8	175.76	216.571	337.974	304.506	41.9505
9	173.592	218.737	339.545	301.461	41.3876
10	171.487	220.924	341.179	298.446	40.8449
11	169.427	223.134	342.849	295.462	40.2909
12	167.504	225.365	344.697	292.507	39.8895
13	165.235	227.619	345.989	289.582	38.7857
14	165.123	229.895	350.552	286.686	41.4307

Source: Made by the authors

Appendix 3. Results for GDP and Debt when Labor tax is 73%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	187.269	202.0	332.33	326.7	76.7303
2	185.794	204.02	332.648	323.433	69.5149
3	183.01	206.06	333.916	320.199	69.8615
4	180.59	208.121	335.043	316.997	68.5679
5	178.164	210.202	336.271	313.827	67.6659
6	175.814	212.304	337.546	310.688	66.7066
7	173.52	214.427	338.881	307.582	65.7886
8	171.286	216.571	340.274	304.506	64.8906
9	169.11	218.737	341.723	301.461	64.0145
10	166.997	220.924	343.239	298.446	63.1708
11	164.918	223.134	344.776	295.462	62.3061
12	163.006	225.365	346.542	292.507	61.662
13	160.65	227.619	347.599	289.582	60.1436
14	160.619	229.895	352.194	286.686	62.707

Source: Made by the authors

Appendix 4. Results for GDP and Debt when Capital tax is 17%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	201.077	202.0	325.518	326.7	12.5179
2	197.986	204.02	326.898	323.433	18.5972
3	196.252	206.06	327.461	320.199	17.3868
4	194.343	208.121	328.208	316.997	17.3557
5	192.505	210.202	328.978	313.827	17.1388
6	190.7	212.304	329.798	310.688	16.956
7	188.933	214.427	330.663	307.582	16.7718
8	187.203	216.571	331.574	304.506	16.592
9	185.509	218.737	332.531	301.461	16.4152
10	183.852	220.924	333.536	298.446	16.2438
11	182.225	223.134	334.576	295.462	16.0642
12	180.674	225.365	335.725	292.507	15.96
13	178.905	227.619	336.532	289.582	15.4123
14	178.748	229.895	339.792	286.686	17.6405

Source: Made by the authors

Appendix 5. Results for GDP and Debt when Capital tax is 45%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	202.519	202.0	329.426	326.7	38.8259
2	203.42	204.02	327.163	323.433	37.7282
3	204.091	206.06	325.069	320.199	38.1492
4	204.853	208.121	322.937	316.997	38.3076
5	205.647	210.202	320.804	313.827	38.5242
6	206.487	212.304	318.663	310.688	38.7416
7	207.371	214.427	316.514	307.582	38.9704
8	208.301	216.571	314.358	304.506	39.209
9	209.278	218.737	312.194	301.461	39.4579
10	210.303	220.924	310.023	298.446	39.7183
11	211.376	223.134	307.838	295.462	39.9848
12	212.514	225.365	305.667	292.507	40.2884
13	213.623	227.619	303.362	289.582	40.46
14	215.235	229.895	301.736	286.686	41.4402

Source: Made by the authors

Appendix 6. Results for GDP and Debt when Capital tax is 73%

Time	GDP	GDPtarget	Debt	Debttarget	G/GDP(%)
1	195.223	202.0	320.851	326.7	52.6508
2	198.219	204.02	317.011	323.433	56.5096
3	201.982	206.06	312.709	320.199	57.1484
4	205.836	208.121	308.387	316.997	58.5013
5	209.925	210.202	303.951	313.827	59.7925
6	214.234	212.304	299.415	310.688	61.1797
7	218.779	214.427	294.771	307.582	62.6357
8	223.57	216.571	290.014	304.506	64.17
9	228.62	218.737	285.139	301.461	65.7857
10	233.939	220.924	280.137	298.446	67.4836
11	239.549	223.134	275.017	295.462	69.2841
12	245.418	225.365	269.701	292.507	71.1089
13	251.793	227.619	264.541	289.582	73.3792
14	257.511	229.895	257.715	286.686	73.9958

Source: Made by the authors