Debt Sustainability and Welfare along an Optimal Laffer Curve*

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Abstract

A recent literature on sovereign debt sustainability (see Trabandt and Uhlig (2011) and Mendoza et al. (2014)) has produced Laffer curve calculations for Eurozone countries. These calculations have been carried out mainly in a quasi-static fashion by considering policy experiments where individual tax rates are permanently set at a new value while keeping all others constant. However, such fiscal policy design disregards complementarities among tax instruments as well as the potential for altering tax rates during the transition to the steady-state in a manner which exploits expectations. Our paper addresses this issue by considering policy experiments where fiscal policy is set optimally and fiscal instruments are jointly varied along the transition to steady-state. Through the Ramsey problem we map the maximum amount of tax revenues a government can further raise to the welfare costs of the associated tax distortions. We label this relation as the 'optimal Laffer curve'. We show that tax revenue and welfare gains relative to the policy experiments examined by the previous literature are dramatic.

Keywords: Laffer Curve, Optimal Policy, Fiscal Sustainability, Fiscal Limit, Fiscal Consolidations

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1 Introduction

Since Jude Wannisky's article in the 1970s, the Laffer curve has been the object of intense debate and the theoretical reference for a series of tax reforms. Much of this popularity is due to its simple interpretation and powerful implications. It implies that taxes and fiscal revenues are related by an inverted-U relationship. Progressive tax hikes are increasingly distortionary and eventually reduce tax revenues. In particular, the closer an economy is to the peak of the Laffer curve, the more self-defeating a tax hike will be and the lower the fiscal space for reducing any deficit.

More recently, the increase in debt-to-GDP ratios in a number of economies, particularly following the financial crisis and the associated increased risk of sovereign default, has triggered renewed interest in the Laffer curve as a means of assessing the sustainability of government finances. A large number of papers have investigated Laffer curves using a variety of economic models.[1] They seek to answer questions, such as: at which point on the Laffer curve is a particular country? To what extent might a tax increase be self-defeating, or a tax cut self-financing? And what is the sustainable level of government debt?

Despite this intense research effort, Laffer curve calculations have tended to be relatively mechanical. Typically, the conventional Laffer curve calculation for an individual tax is constructed by progressively varying its rate from 0% to 100%, while keeping all other fiscal instruments fixed. Moreover, a one-off permanent change in a single tax rate is often assumed in constructing the Laffer curve. However, these conventional approaches ignore two crucial issues. First, there is likely to be some degree of complementarity between fiscal instruments, such that appropriately designing the tax mix will generate more revenue than an instrument-by-instrument approach. Second, in a dynamic economy, the profile of fiscal instruments over time is likely to be important in assessing the discounted revenues generated. This is due to the fact that the tax elasticity of production factors varies over time, and tax

[1] Those studies include Bruce and Turnovsky (1999), Agell and Persson (2001), Novales and Ruiz (2002),Mankiw and Weinzierl (2006), Leeper and Yang (2008), Trabandt and Uhlig (2011) and Mendoza et al. (2014).

revenues raised in the distant future matter less in present value terms.

Our paper attempts to address these issues by allowing fiscal policy to be conducted optimally. Therefore, the policy maker can vary both the level and the composition of fiscal instruments over time to achieve the maximum attainable tax revenues for a given welfare loss due to tax distortions. We then compare tax revenues under optimal policy with those implied by the conventional Laffer curve calculations considered by Trabandt and Uhlig (2011) and Mendoza et al. (2014). We show that the increase in tax revenues raised per unit of welfare loss is dramatic when the policy maker can vary multiple tax instruments over time. This result holds even when we allow for debt service costs to rise with debt levels and policy maker myopia. Our study implies that the previous literature significantly underestimates the sustainable level of government debt, or equivalently, overstates the welfare losses of achieving a given level of fiscal revenues.

Locating Our Contribution within the Related Literature

The European sovereign debt crisis of 2009-2011 has generated widespread interest in measuring the sustainability of government debt. In the new Handbook of Macroeconomics, D'Erasmo et al. (2015) identifies three main approaches to assessing fiscal sustainability. The first is empirical based on the estimation of fiscal reaction functions in the spirit of Bohn (2005). The latter two rely on calibrated theoretical models which either look at the government's optimal default decision (see Mendoza (2013) and Dovis et al. (2014)) or the fiscal limit (Mendoza et al. (2014) and Trabandt and Uhlig (2011)). The former approach asks what debt the government is prepared to support optimally, while the latter what debt it could potentially support. Whether or not the revenues implied by this final exercise can actually be attained then depends upon the credibility of the government's policies.

Our research builds on this latter literature which seeks to compute the fiscal limit, which is underpinned by the Laffer curve. The peak of the Laffer curve defines the maximum tax revenues which can be generated given the fiscal experiment considered. It serves as a measure of potential fiscal sustainability. The literature in this field has carried out fiscal limit calculations for groups of countries by constructing Laffer curves for appropriately calibrated model economies.

Trabandt and Uhlig (2011) have provided Laffer curve calculations by considering the steady-state economies calibrated to represent key European countries.[2] Their exercise is regarded as the conventional Laffer curve calculation where a curve for each tax instrument is constructed by letting its rate vary from 0% to 100%, while holding all the remaining fiscal instruments fixed. Similarly, Mendoza et al. (2014) have undertaken these calculations in the context of dynamic open economies to account for transitional dynamics and international spillovers. However, they also assume a one-off permanent change in a single tax rate as in Trabandt and Uhlig (2011). As a result, these calculations suggest that failing to account for transitional dynamics does not materially affect the construction of the Laffer curve.[3]

Our paper seeks to reconcile these conventional Laffer curve calculations with optimal policy results. In doing so, we produce an object we label the 'optimal Laffer curve', which plots a Laffer curve in welfare loss-sustainable debt space. Differently from the existing literature, we let the fiscal policy underpinning the Laffer curve be determined through an optimal policy problem. We employ the workhorse Neoclassical model allowing for variable capacity utilization of capital as in Mendoza et al. (2014).[4] In this environment, we study the maximum amount of tax revenues a government can raise for a given level of social welfare when policy is set optimally. In doing so,

[2]Trabandt and Uhlig (2011) also conduct a robustness check on the significance of allowing for transitional dynamics. In the case of a labor income tax, transitional dynamics, following a permanent shift in the tax rate, make little difference. While the case of capital income tax is complicated by the fact the policy maker can exploit the initial holdings of capital in a non-distortionary way.

[3]Bi (2012) adopts a different approach to computing the fiscal limit which is closer in spirit to what we do. She considers a simple stochastic economy without capital and can analytically compute the peak of the Laffer curve in every period conditional on the realization of a technology shock. These conditional maximum revenues can then be combined to generate a distribution of the fiscal limit. Our model is richer, containing both capital and multiple fiscal instruments such that computing the Laffer curve is non-trivial.

[4]As shown in Mendoza et al. (2014) and Ferraro (2010), variable capacity utilization overturns the ability of the policy maker to tax initial holdings of capital in a lump-sum way. Effectively, the holders of capital choose to decrease their rate of utilization rather than allow the policy maker to tax them. The policymaker is, therefore, less able to exploit a predetermined tax base.

we extend the existing literature in a number of ways.

First, our approach takes full account of the dynamic path towards the eventual steady-state and allows tax rates to vary over time. We find that exploiting these transitional dynamics can often account for much of the tax revenue raising capability of the government under optimal policy. We show that both the steady-state or dynamic analyses with constant tax rates which underpin conventional Laffer curve calculations significantly understate the potential fiscal limit as a result.

Second, we allow tax instruments to be varied simultaneously rather than, as in the conventional Laffer curve calculations, sequentially varying one instrument while holding all others fixed. The ability to vary multiple tax rates over time allows the policy maker to generate significantly higher revenues by committing to gradually eliminate capital income taxation in the long run, while, at the same time, slowly switching to labor income taxation.

Third, our optimal Laffer curve, plotted in welfare loss-sustainable debt space, combines the various tax distortions in a single welfare measure. We can map existing measures of the Laffer curve into the same space as our optimal Laffer curve and in doing so we can highlight how policy recommendations change both in steady-state and transition. Our findings suggest that these policy recommendations will be radically different.

Finally, we consider a number of extensions to our baseline model which include risk premia on government debt and policy maker myopia. Those extensions impact on the trade-offs which are so finely balanced in the benchmark optimal policy exercise.[5] Specifically, risk premia on government debt gives rise to incentives to stabilize debt quickly, while policy maker myopia captures the opposite tendency to delay fiscal adjustment. We show that the potential gains in terms of welfare and/or debt sustainability achieved when implementing fiscal policy optimally are robust to such extensions.

[5] Optimal policy in our baseline model will inherit one of the key features of tax smoothing whereby the policies sustaining steady-state debt will ensure that the discounted long-run benefits of reducing debt exactly match the short-run costs of doing so. This further implies that where this balancing point is found will define the steady-state level of debt which, in turn, depends on the initial debt level.

The remainder of the paper is structured as follows. Section 2 presents the main features of our model economy, while in Section 3 we describe the Ramsey problem solved by the government. Section 4 discusses the calibration strategy and introduces the optimal Laffer curve. In Section 5 we contrast our optimal Laffer curve with conventional analyses which examine one-off permanent changes in a single tax instrument. Robustness and extensions which include risk premia on debt and policy maker myopia are considered in Section 6. Section 7 concludes.

2 The Model Economy

Our baseline model follows the closed economy of Mendoza et al. (2014). The model economy features exogenous growth, at rate γ, which is driven by labor-augmenting technological change. Accordingly, all variables (except labor, leisure and the interest rate) are rendered stationary by dividing them by the level of technology.[6] This stationarity-inducing transformation of the model requires discounting the re-scaled utility flows at the rate $\widetilde{\beta} = \beta\left(1+\gamma\right)^{1-\sigma}$ where β is the standard subjective discount factor of time-separable preferences, and adjusting the laws of motion of physical and financial assets so that date $t+1$ stocks grow by the balanced-growth factor $1+\gamma$.

2.1 Households

The utility function of the representative household in our economy is

$$\sum_{t=0}^{\infty} \widetilde{\beta}^{t} U\left(c_t, 1-l_t\right), \tag{1}$$

where we assume the period utility function is a standard CRRA function in terms of a CES composite good made of consumption, c_t, and leisure, $1-l_t$

[6] We could have presented the model in its non-stationary form and then undertaken the transformation of the equilibrium conditions at the end. This is equivalent to undertaking the scaling by technology when setting up the model, as we do.

as follows:

$$U(c_t, 1-l_t) = \frac{[c_t(1-l_t)^a]^{1-\sigma}}{1-\sigma}, \sigma > 1, \text{ and, } a > 0.$$

The household's budget constraint is given by,

$$(1+\tau_t^c)c_t + x_t + (1+\gamma)q_t d_{t+1} = (1-\tau_t^l)w_t l_t + (1-\tau_t^k)r_t m_t k_t + \theta\tau_t^k\overline{\delta}k_t + d_t + e_t, \quad (2)$$

where τ_t^c, τ_t^l and τ_t^k are proportional tax rates on consumption, c_t, labor income, $w_t l_t$, and capital income, $r_t m_t k_t$, respectively. $\theta\tau_t^k\overline{\delta}$ is a capital tax depreciation allowance which is based on average rates of depreciation and only applies to a fraction of the capital stock since $\theta < 1$. Households also receive a lump-sum transfer from the government, e_t, which is treated as being exogenous and sets to its steady-state value ($e_t = \bar{e}$). Finally, the household saves in the form of physical capital, k_{t+1}, as well as government bonds, d_{t+1}, which are priced at q_t.

Gross investment, x_t, is defined as,

$$x_t = (1+\gamma)k_{t+1} - [1-\delta(m_t)]\,k_t + \phi(k_{t+1}, k_t, m_t), \quad (3)$$

where the depreciation rate depends on the rate of capital utilization m_t as follows,

$$\delta(m_t) = \frac{\chi_0 m_t^{\chi_1}}{\chi_1}, \; \chi_0 > 0 \text{ and } \chi_1 > 1, \quad (4)$$

and capital adjustment costs are defined as,

$$\phi(k_{t+1}, k_t, m_t) = \frac{\eta}{2}\left\{\frac{(1+\gamma)k_{t+1} - [1-\delta(m_t)]\,k_t}{k_t} - z\right\}^2 k_t,$$

where η determines the speed of adjustment of the capital stock and z is the long-run investment-capital ratio which removes adjustment costs from the steady-state.

The household chooses the path of consumption, leisure, government bonds, investment and the rate of capital utilization to maximize utility (1) subject to the budget constraint (2) and the law of motion for capital

(3). Its optimization yields the following set of first order conditions.[7] The consumption Euler equation,

$$(1+\gamma)q_t = \widetilde{\beta}\frac{U'_{c_{t+1}}(c_{t+1}, 1-l_{t+1})}{U'_{c_t}(c_t, 1-l_t)}\frac{1+\tau_t^c}{1+\tau_{t+1}^c}, \tag{5}$$

consumption-leisure margin,

$$-\frac{U'_{l_t}(c_t, 1-l_t)}{U'_{c_t}(c_t, 1-l_t)} = \frac{1-\tau_t^l}{1+\tau_t^c}w_t, \tag{6}$$

gross investment,

$$\begin{aligned} & \frac{U'_{c_t}(c_t, 1-l_t)}{(1+\tau_t^c)}\left[1+\gamma+\phi'_{k_{t+1}}(k_{t+1}, k_t, m_t)\right] \qquad (7) \\ = \; & \widetilde{\beta}\frac{U'_{c_{t+1}}(c_{t+1}, 1-l_{t+1})}{(1+\tau_{t+1}^c)}\left[\begin{array}{c} 1-\delta(m_{t+1})-\phi'_{k_{t+1}}(k_{t+2}, k_{t+1}, m_{t+1}) \\ +(1-\tau_{t+1}^k)r_{t+1}m_{t+1}+\theta\tau_{t+1}^k\overline{\delta} \end{array}\right], \end{aligned}$$

and, finally, capital utilization condition,

$$(1-\tau_t^k)r_t k_t = \delta'_{m_t}(m_t)k_t + \phi'_{m_t}(k_{t+1}, k_t, m_t). \tag{8}$$

2.2 Firms

Firms rent labor, l_t, and capital services, s_t, from households at a given wage, w_t, and capital rental rate, r_t, to maximize profits,

$$\Pi_t = y_t - w_t l_t - r_t s_t,$$

subject to a production function which is assumed to be of the Cobb-Douglas form,

$$y_t = F(s_t, l_t) = s_t^{1-\alpha} l_t^{\alpha}.$$

The firms' maximization problem gives rise to standard first order condi-

[7] We use the notation $f'_{x_t}(.)$ to denote the partial derivative of function $f(.)$ with respect to argument x_t.

tions

$$F'_{s_t}(s_t, l_t) = r_t, \tag{9}$$

and

$$F'_{l_t}(s_t, l_t) = w_t, \tag{10}$$

while linear homogeneity implies $y_t = w_t l_t + s_t k_t$.

2.3 Public Sector

The government's budget constraint is given by,

$$d_t - (1+\gamma) q_t d_{t+1} = pb_t, \tag{11}$$

where the primary balance, pb_t, is defined as,

$$pb_t = \tau_t^c c_t + \tau_t^l w_t l_t + \tau_t^k (r_t m_t - \theta\bar{\delta}) k_t - (g_t + e_t),$$

where government consumption, g_t, is set to its steady-state value $g_t = \bar{g}$.

2.4 Market Clearing

Market clearing in the goods market requires:

$$F(s_t, l_t) = c_t + g_t + (1+\gamma) k_{t+1} - [1 - \delta(m_t)]\, k_t + \phi(k_{t+1}, k_t, m_t), \tag{12}$$

while capital market clearing implies that

$$m_t k_t = s_t. \tag{13}$$

2.5 The Competitive Equilibrium

The equilibrium of our model consists of a sequence of prices $\{w_t,\ r_t,\ q_t\}_{t=0}^{\infty}$, government policy $\{\tau_t^c,\ \tau_t^l,\ \tau_t^k,\ d_{t+1}\}_{t=0}^{\infty}$ and allocations $\{c_t,\ l_t,\ s_t,\ x_t,\ m_t,\ k_{t+1}\}_{t=0}^{\infty}$ such that:

- $\{c_t, l_t, x_t, m_t, k_{t+1}, d_{t+1}\}_{t=0}^{\infty}$ solves the households' problem given prices and government policy;

- $\{s_t, l_t\}_{t=0}^{\infty}$ solves firms' problem given prices;

- The government's budget constraint (11) holds for all $t \geq 0$;

- All markets clear as in (12) and (13).

The definition above implies that for any government policy $\{\tau_t^c, \tau_t^l, \tau_t^k, d_{t+1}\}_{t=0}^{\infty}$, satisfying the government budget constraint (11), we have a different competitive equilibrium. In Section 3, we describe the optimal policy problem that selects the policy corresponding to the government's desired equilibrium. However, before considering such a problem, we need to put some structure on which instruments the government has access to.

The distortionary taxes in our model act on three margins. The first margin is the intratemporal consumption-leisure decision obtained by combining the first order conditions (6) and (10),

$$-\frac{U'_{l_t}(c_t, 1-l_t)}{U'_{c_t}(c_t, 1-l_t)} = \frac{1-\tau_t^l}{1+\tau_t^c} F'_{l_t}(m_t k_t, l_t). \tag{14}$$

The second margin is the intertemporal investment decision which is obtained by combining equations (7) and (9),

$$\begin{aligned} & \frac{U'_{c_t}(c_t, 1-l_t)}{(1+\tau_t^c)} \left[1 + \gamma + \phi'_{k_{t+1}}(k_{t+1}, k_t, m_t)\right] \qquad (15) \\ = \; & \widetilde{\beta} \frac{U'_{c_{t+1}}(c_{t+1}, 1-l_{t+1})}{(1+\tau_{t+1}^c)} \left[\begin{array}{c} (1-\tau_t^k) F'_{s_{t+1}}(m_{t+1}k_{t+1}, l_{t+1}) m_{t+1} + 1 - \delta(m_{t+1}) \\ -\phi'_{k_{t+1}}(k_{t+2}, k_{t+1}, m_{t+1}) + \theta \tau_{t+1}^k \overline{\delta} \end{array} \right]. \end{aligned}$$

Finally, combining equations (8) and (9) gives rise to the third margin, namely, the capital utilization condition,

$$(1-\tau_t^k) F'_{s_t}(m_t k_t, l_t) k_t = \delta'_{m_t}(m_t) k_t + \phi'_{m_t}(k_{t+1}, k_t, m_t). \tag{16}$$

The labor tax, τ_t^l, can distort the first margin; the consumption tax, τ_t^c, distorts the first and second, while the capital tax, τ_t^k, affects the latter two.

In the case of the intratemporal consumption-leisure and investment decision, if labor income is subsidized at the same constant rate as the policy maker taxes consumption (i.e. $-\tau_t^l = \tau_t^c = \tau$), it will eliminate these distortions. Given that those taxes and subsidies are then applied to different tax bases, this would enable the Ramsey policy maker to generate fiscal revenues without suffering any distortions.[8] It effectively gives them access to a lump-sum tax and renders the policy problem trivial. Since in the real world a lump-sum tax is typically not available, we rule out this possibility by fixing τ_t^c at a calibrated value consistent with the data, $\tau_t^c = \tau^c$.[9] Therefore, the capital and labor tax rates are the only fiscal instruments available to the Ramsey policy maker. Furthermore, in order to make the analytical solution of our Ramsey problem more tractable, we remove capital adjustment costs and capital depreciation allowances by setting $\eta = 0$ and $\theta = 0$ as in Debortoli and Nunes (2010). We will explore the implications of relaxing these assumptions in the robustness exercises in Section 6.

3 Ramsey Policy with Endogenous Capacity Utilization

In this section, we characterize the solution of the Ramsey model with endogenous capacity utilization. Under Ramsey policy, the policy maker chooses the sequences of labor and capital taxes and the implied path for debt, $\{\tau_t^l,\, \tau_t^k,\, d_{t+1}\}_{t=0}^{\infty}$, so as to maximize life-time utility. This problem is time inconsistent and we assume that government has access to a commitment technology.

We seek to make three main points which underpin the construction of our optimal Laffer curve in Section 4. First, the famous Chamley-Judd result (see Chamley (1986) and Judd (1985)) applies to our model. In the short-run the capital tax rate is positive as the Ramsey planner exploits the (quasi) lump-sum nature of the tax on the initial capital. However, in the long-run

[8] Under such a tax policy the policy could also optimally set the capital tax rate to zero, $\tau_t^k = 0$.

[9] This is because, typically, $\tau^c \neq \tau$.

the capital tax approaches zero as the Ramsey planner attempts to raise revenues through the least distortative instrument which is the labor income tax. Second, with endogenous capacity utilization the tax on the initial stock of capital is bounded. In our model the presence of endogenous capacity utilization makes the capital base elastic in the short-run, limiting the extent to which the Ramsey planner can exploit this margin. This is in contrast to Chamley-Judd where capacity utilization is fixed. Third, the Ramsey policy features a unit root in steady-state debt. The steady-state level of debt the economy eventually achieves depends upon the initial level of debt the policy maker inherits.

To illustrate those three points, we follow Lucas and Stokey (1983) in writing the Ramsey policy problem in the primal form that solves for allocations only. Once allocations have been determined, prices and policy can be recovered from the competitive economy's equilibrium conditions.

3.1 The Primal Form

Our Ramsey problem in primal form consists of maximizing utility in (1) subject to four constraints. The first is the resource constraint implied by the market clearing conditions in the goods (12) and capital (13) markets, respectively,

$$F(m_t k_t, l_t) - c_t - g_t - (1+\gamma)k_{t+1} + [1-\delta(m_t)]\, k_t \geq 0. \tag{17}$$

The second constraint is the implementability constraint[10]

$$B - \sum_{t=0}^{\infty} \widetilde{\beta}^t \left[U'_{c_t}(c_t, 1-l_t) \left(c_t - \frac{\overline{e}}{1+\tau^c} \right) + U'_{l_t}(c_t, 1-l_t)\, l_t \right] \geq 0, \tag{18}$$

where B collects all period-0 terms such that

$$B \equiv \left\{ d_0 + \left[\left(1-\tau_0^k\right) F'_{s_0}(m_0 k_0, l_0) m_0 \;+\; \left(1-\delta\left(m_0\right)\right) \right] k_0 \right\} \frac{U'_{c_0}(c_0, 1-l_0)}{1+\tau^c}.$$

[10]The derivation of the implementability constraint is shown in Appendix B.1.

The resource and the implementability constraints are standard in the optimal policy literature, while the third constraint is due to the presence of endogenous capacity utilization. It is obtained by combining the intertemporal investment decision (15) and capital utilization condition (16) after leading the latter forward one period [11],

$$\frac{U'_{c_t}\left(c_t, 1-l_t\right)}{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)} = \frac{\widetilde{\beta}}{1+\gamma}\left[\delta'_{m_{t+1}}(m_{t+1})m_{t+1} + 1 - \delta(m_{t+1})\right]. \tag{19}$$

However, by leading the capital utilization condition (16) one-period forward, we omitted this condition at period-0 in the third constraint.

Therefore, we need to reintroduce the period-0 capital utilization condition,

$$\left(1-\tau_0^k\right) F'_{s_0}(m_0 k_0, l_0) = \delta'_{m_0}\left(m_0\right), \tag{20}$$

as a fourth constraint.

It is convenient to group all terms in the primal policy problem involving the utility function together as,

$$\begin{aligned} V(c_t, 1-l_t, \phi, \lambda_t^1) = \; & U\left(c_t, 1-l_t\right) \\ & + \phi\left[U'_{c_t}\left(c_t, 1-l_t\right)\left(c_t - \frac{\overline{e}}{1+\tau^c}\right) + U'_{l_t}\left(c_t, 1-l_t\right) l_t\right] \\ & + \lambda_t^1\left[\left(\frac{1+\gamma}{\widetilde{\beta}}\right)\frac{U'_{c_t}\left(c_t, 1-l_t\right)}{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)}\right], \end{aligned}$$

where ϕ and λ_t^1 are multipliers associated with the second constraint (18) and the third constraint (19), respectively. This expression can then be treated as the policy objective in a more compact representation of the Lagrangian describing the underlying policy problem, as follows,[12]

[11] As discussed above, we temporarily remove capital adjustment costs and capital depreciation allowances to make the analytical solution of our Ramsey problem more tractable.

[12] The details of the Lagrangian function are shown in Appendix B.2.

$$\max_{\{c_t,l_t,m_t,k_{t+1},\tau_0^k\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left\{ \begin{array}{c} V(c_t, 1-l_t, \phi, \lambda_t^1) \\ -\lambda_t^1 \left[\delta'_{m_{t+1}}(m_{t+1})m_{t+1} + 1 - \delta(m_{t+1})\right] \\ +\lambda_t^2 \left[F(m_t k_t, l_t) - c_t - \overline{g} - (1+\gamma)k_{t+1} + (1-\delta(m_t))\, k_t\right] \end{array} \right\} - \phi A,$$

where λ_t^2 is the multiplier attached to the resource constraint (17) and

$$A \equiv B - \frac{\varphi}{\phi}\left[\left(1-\tau_0^k\right) F'_{s_0}(m_0 k_0, l_0) - \delta'_{m_0}(m_0)\right].$$

Here, the term A captures all the period-0 constraints including B in the implementability constraint (18) and the period-0 capital utilization condition (20), where φ is the multiplier attached to this condition.

The first order conditions for $t \geq 0$ are:

$$\{c_t\} : V'_{c_t}(c_{t-1}, 1-l_{t-1}, \phi, \lambda_{t-1}^1) + \widetilde{\beta} V'_{c_t}(c_t, 1-l_t, \phi, \lambda_t^1) = \widetilde{\beta}\lambda_t^2, \tag{21}$$

$$\{l_t\} : V'_{l_t}(c_{t-1}, 1-l_{t-1}, \phi, \lambda_{t-1}^1) + \widetilde{\beta} V'_{l_t}(c_t, 1-l_t, \phi, \lambda_t^1) = -\widetilde{\beta}\lambda_t^2 F'_{l_t}(m_t k_t, l_t), \tag{22}$$

$$\{m_t\} : \lambda_{t-1}^1 \delta''_{m_t}(m_t) m_t = \widetilde{\beta}\lambda_t^2 \left[F'_{m_t}(m_t k_t, l_t) - \delta'_{m_t}(m_t)\right] k_t, \tag{23}$$

$$\{k_{t+1}\} : \widetilde{\beta}\lambda_{t+1}^2 \left[F'_{k_{t+1}}(m_{t+1}k_{t+1}, l_{t+1}) m_{t+1} + 1 - \delta(m_{t+1})\right] = \lambda_t^2 (1+\gamma), \tag{24}$$

$$\{c_0\} : V'_{c_0}(c_0, 1-l_0, \phi, \lambda_0^1) = \lambda_0^2 + \phi A'_{c_0}, \tag{25}$$

$$\{l_0\} : V'_{l_0}(c_0, 1-l_0, \phi, \lambda_0^1) = -\lambda_0^2 F'_{l_0}(m_0 k_0, l_0) + \phi A'_{l_0}, \tag{26}$$

$$\{m_0\} : \lambda_0^1 \delta''_{m_0}(m_0) m_0 = \lambda_0^2 \left[F'_{m_0}(m_0 k_0, l_0) - \delta'_{m_0}(m_0)\right] k_0 + \phi A'_{m_0}, \tag{27}$$

$$\left\{\tau_0^k\right\} : \phi \frac{U'_c(c_0, 1-l_0)}{1+\tau^c} F'_{k_0}(m_0 k_0, l_0) m_0 k_0 - \varphi F'_{k_0}(m_0 k_0, l_0) = 0. \tag{28}$$

The above set of first order conditions (21)-(28) and the four constraints characterize the solution of the Ramsey problem.

3.2 Long-run capital tax of zero

The famous long-run zero-capital tax applies to our model with endogenous capacity utilization. To illustrate this point, we compare the steady-state solution of the Ramsey first order condition for capital (24),

$$\widetilde{\beta}\left[F_k'(mk,l)m + 1 - \delta(m)\right] = 1 + \gamma, \tag{29}$$

to the intertemporal investment decision (15) implied by the competitive equilibrium[13]

$$\widetilde{\beta}\left[(1-\tau^k)F_k'(mk,l)m + 1 - \delta(m)\right] = 1 + \gamma. \tag{30}$$

Since the Ramsey allocation is a competitive equilibrium, equations (29) and (30) imply that the Ramsey capital tax, τ^k, is zero in the long-run.

3.3 Taxation of initial capital

In our model with endogenous capacity utilization, the first order condition with respect to the period-0 capital tax, τ_0^k, in (28),

$$\phi \frac{U_c'(c_0, 1-l_0)}{1+\tau^c} F_{k_0}'(m_0 k_0, l_0) m_0 k_0 - \varphi F_{k_0}'(m_0 k_0, l_0) = 0,$$

offers an insight of why the initial capital tax is bounded. In particular, the term, $\varphi F_{k_0}'(m_0 k_0, l_0)$, appears in the above first order condition because endogenous capital utilization introduces a distortionary component to the period-0 capital tax. The multiplier, φ, measures the costs of adjusting capacity utilization, while ϕ represents the benefits associated with lower future distortions implicit in the present value of the budget constraint. As the government increases the capital tax, households will reduce capacity utilization. Therefore, when setting initial capital taxation, the Ramsey planner will need to balance the benefits associated with lower future distortions with

[13]With $\eta = \theta = 0$, the terms associated with capital adjustment costs, $\phi_{k_{t+1}}'(k_{t+1}, k_t, m_t)$ and $\phi_{k_{t+1}}'(k_{t+2}, k_{t+1}, m_{t+1})$, and capital depreciation allowances, $\theta\tau_t^k\overline{\delta}$, disappear in equation (15). Therefore, the steady-states of those terms also disappear in equation (30).

the counteracting short-run costs associated with reduced capacity utilization.

This is in contrast to the corresponding condition in Chamley-Judd with an exogenous fixed utilization rate,

$$\phi \frac{U'_{c_0}\left(c_0, 1-l_0\right)}{1+\tau^c} F'_{k_0}\left(k_0, l_0\right) k_0 > 0,$$

where the period-0 stock of capital, k_0, is given and the capital tax rate is effectively a lump sum tax. Therefore, under Chamley-Judd without endogenous capital utilization, it is optimal to set the capital tax rate as high as needed to drive ϕ to zero.

3.4 The unit root in steady-state debt

While the steady-state rate of capital tax has been shown to be zero, the long-run value of the labor tax depends on the initial level of debt, d_0. This can be seen from the fact that the Lagrange multiplier of the implementability constraint, ϕ, enters the first order condition with respect to labor supply in (22) which pins down the labor tax rate. Since the value of this Lagrange multiplier captures the burden of initial debt, this links the Ramsey initial conditions to the steady-state rate of labor taxation. Therefore, a higher initial level of debt will result in a higher long-run labor tax to support a higher long-run debt level, *ceteris paribus*. Intuitively, our model features a form of tax smoothing which seeks to balance tax distortions over time, while at the same time satisfying the government's intertemporal budget constraint. In steady-state this means that the costs of transitory tax distortions which could reduce debt are exactly offset by the discounted value of the gains of that lower debt, such that the policy maker prefers to maintain debt at that higher level rather than act to return debt to a unique steady-state value.

Moreover, from the logic of the original Laffer curve, there are two steady-states associated with any initial debt level: one with a high and the other with a low value of the labor tax. Therefore, for a given initial level of government debt, there will be two potential steady-states which satisfy the Ramsey first order conditions. We can trace out the set of sustainable debt levels by varying the initial level of debt and assessing the two possible policy paths which both sustain that debt. Computing the welfare costs of each policy path then gives us two points on either side of our optimal Laffer curve which we will show in Section 4.

4 Optimal Laffer Curve

4.1 Calibration

Before constructing our optimal Laffer curve, we need to calibrate our baseline model presented in Section 2. Our model is calibrated at a quarterly frequency on the 15 largest countries in the Eurozone[14]. In general, our parametrization tracks closely Mendoza et al. (2014) and D'Erasmo et al. (2015), not only because we employ the same model for analyzing the fiscal position of the same group of countries, but also to keep our results directly comparable with theirs. Our calibration is reported in Table 1.

Beginning with technology parameters, the labor share of production is set to 0.61, a value in line with Trabandt and Uhlig (2011) and Mendoza et al. (2014). The quarterly rate of labor augmenting technological change, γ, is set to 0.0022. This reflects a 0.9% annual average growth rate in real GDP per capita observed in Eurozone between 2000 and 2011. The depreciation function in (4) requires setting two parameters, χ_0 and χ_1. First, to calibrate χ_0, we use the steady-state of the capital utilization constraint (19) which implies that $\chi_0 m^{\chi_1} = \left(1+\gamma-\widetilde{\beta}\right)/\widetilde{\beta} + \delta(m)$, and we normalize the long-run capacity utilization rate to $m = 1$. In order to match the long-run depreciation rate $\delta(m) = 0.0164$, a value in line with Mendoza et al. (2014) and D'Erasmo et al. (2015), χ_0 is set to 0.0266. Second, given the values of m, $\delta(m)$ and χ_0, $\chi_1 = 1.628$ which is derived from the depreciation function (4) in steady-state.

For preference parameters, σ is set to 2 to deliver the commonly used

[14] Specifically, those countries include Austria, Belgium, Estonia, Finland, France, Germany, Luxembourg, the Netherlands, the Slovak Republic, Slovenia, Italy, Spain, Portugal, Greece and Ireland.

intertemporal elasticity of substitution of 0.5. The leisure utility parameter, α, is set to 2.675. This returns the average of 18.2 hours per week for a person aged between 15 to 64 in France, Germany and Italy, reported in Prescott (2004). The households' discount factor, β, is set to 0.9942 such that $\widetilde{\beta} = \beta (1+\gamma)^{1-\sigma} = 0.992$. This implies an annual real interest rate of 4.14% as the quarterly gross rate is $R \equiv \beta (1+\gamma)^{\sigma} = 1.0102$.

Fiscal variables include tax rates, government expenditures, transfers and debt. Although in our analysis labor and capital tax rates are solutions of the optimal policy problem, the initial equilibrium of our model is parametrized on the basis of the fiscal regime prior to 2008. In particular, tax rates are set to be consistent with Mendoza et al. (2014), where $\tau^c = 0.16$, $\tau^l = 0.35$ and $\tau^k = 0.20$. Government expenditures is set to be 21% of GDP in line with the OECD definition 'general government consumption expenditure as a percentage of GDP'. In addition, public debt to GDP ratio,$d/4y$, is calibrated to 66% to reflect the debt level in those countries at 2008. Finally, government transfers are determined as the residual of government's budget constraint in (11) such that[15]

$$\frac{e}{y} = \frac{Rev}{y} - \frac{g}{y} - \frac{d}{y}\left(1 - \tilde{\beta}\right) = 0.152,$$

where $Rev \equiv \tau^c c + \tau^l wl + \tau^k (rm - \theta\overline{\delta})k$. In our baseline model we set both depreciation allowances, θ, and capital adjustment costs, η, to zero. When performing robustness we calibrate $\theta = 0.22$ and $\eta = 2$ as in Mendoza et al. (2014).

[15]Note that the consumption Euler equation in steady state implies that $\widetilde{\beta} = (1+\gamma)q$.

Table 1: Calibration

Parameter	Description	Value	Calibration strategy
		Technology	
α	labor income share	0.61	Mendoza et al. (2014)
γ	growth rate	0.0022	GDP p.c. growth EU-15
m	capacity utilization	1	steady-state normalization
$\delta(m)$	depreciation rate	0.0164	Mendoza et al. (2014)
χ_0	$\delta(m)$ coefficient	0.0266	set to yield $\delta(m) = 0.0164$
χ_1	$\delta(m)$ exponent	1.628	set to yield $m = 1$
		Preferences	
$\bar{\beta}$	discount factor	0.992	Mendoza et al. (2014)
σ	risk aversion	2.000	standard RBC value
a	labor supply elasticity	2.675	Mendoza et al. (2014)
		Fiscal Policy	
τ^c	consumption tax	0.16	Mendoza et al. (2014)
τ^l	labor tax	0.35	Mendoza et al. (2014)
τ^k	capital tax	0.20	Mendoza et al. (2014)
$\frac{d}{y}$	govt debt to GDP	0.66	Mendoza et al. (2014)
$\frac{g}{y}$	govt consumption to GDP	0.21	OECD
$\frac{e}{y}$	govt transfer to GDP	0.152	govt budget in SS

4.2 Constructing the Optimal Laffer Curve

To construct the optimal Laffer curve we employ the Ramsey policy discussed in Section 3. Compared to the conventional Laffer curve calculations in Trabandt and Uhlig (2011) and Mendoza et al. (2014), the optimal fiscal policy underneath our Laffer curve allows for variation of multiple tax instruments over time. Specifically, tax plans are constructed accounting for discounting, expectations and the dynamics of production factor elasticities.

We construct our optimal Laffer curve by iteratively solving the Ramsey problem conditional on different amounts of initial government debt. We then recover welfare costs associated with the optimal policy that sustains these debt levels.[16] These welfare costs capture the combined distortions implied by the fiscal mix optimally implemented by the Ramsey planner. We then plot each level of government debt (over GDP) against the implied welfare loss measured in consumption equivalent units.[17] This gives rise to our optimal Laffer curve in Figure 1. Such a curve represents welfare costs of sustaining any amount of government debt when fiscal policy is carried out optimally. It shows the key elements of a policy maker's problem: how much debt can be sustained and at what social cost?

The optimal Laffer curve inherits the bell shape of the conventional Laffer Curve: each amount of debt can be repaid in two ways, one of which is inefficient. This shape results from the properties of the optimal policy problem featuring exogenous government spending and endogenous distortionary taxation and debt. This problem is known to be non-ergodic as its steady-state depends on the initial level of government debt (and capital). However, such a steady state is not unique. In particular, there are two different steady-states satisfying the Ramsey first order conditions. One gives the positive sloping side of our optimal Laffer curve, while the other one features an inefficiently high level of tax distortions and welfare loss which is

[16]The initial government debt corresponds to the present value of tax revenues minus exogenous public spending. Since government spending is exogenous and fixed, the terms, such as the initial government debt, the sustainable government debt or discounted stream of tax revenues, are all equivalent. We can therefore use these terms interchangeably.

[17]See Appendix D for the computation of consumption equivalent units of welfare.

on the downward sloping side of the curve.

Finally, from Figure 1 some interesting insights can be appreciated. In particular, under zero welfare cost, our optimal Laffer curve implies a sustainable debt to GDP ratio of 96% as opposed to 66% supported by the initial calibrated tax policies in Table 1. That means implementing an optimal tax policy can generate an additional 33% of GDP in discounted tax revenues at no welfare cost. In addition, moving along the optimal Laffer curve gives us a sense of the trade-offs facing a policy maker. The highest sustainable debt to GDP ratio is about 224%, with the associated tax distortions being equivalent to a welfare loss of 16.7% of steady-state consumption.

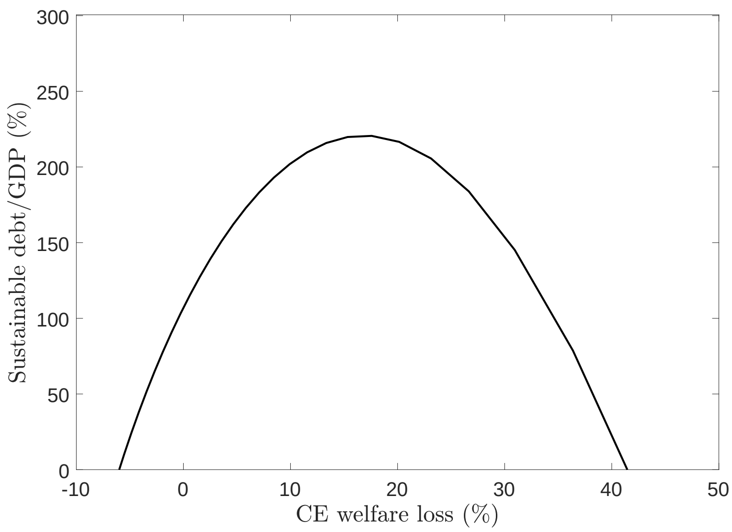

Figure 1: Optimal Laffer Curve

5 Optimal Laffer Curve versus Conventional Laffer Curve

We now turn to explore how our optimal Laffer curve compares to the conventional Laffer curves of Trabandt and Uhlig (2011) and Mendoza et al. (2014) to assess to what extent these latter calculations leave potential revenue or welfare gains unexploited by failing to conduct policy optimally. As Trabandt and Uhlig (2011) focus on a steady-state economy, whereas Mendoza et al. (2014) on a dynamic one, we consider these cases separately. Although in the conventional Laffer curve calculation, a dynamic analysis does not seem to be radically different from a steady-state one, we show that transitional dynamics can be hugely important when policy is conducted optimally. This is due to the fact that while the economy may be dynamic, the fiscal policies considered in conventional analyses are both static and rely on only varying one fiscal instrument at a time. Relaxing these assumptions can generate significant tax revenues and/or welfare gains.

5.1 Steady-State Laffer Curves

In this subsection, we first compare our optimal Laffer curve with the steady-state Laffer curve calculation carried out by Trabandt and Uhlig (2011), 'Trabandt-Uhlig' henceforth. Trabandt-Uhlig's calculation is produced by considering the economy at its steady-state and constructing two curves: the capital and the labor Laffer curve. Those curves are obtained by fixing all tax rates but one and observing how fiscal revenues change as the latter is varied from 0 to 100%. For most of their analysis transitional dynamics are disregarded, that is, following a policy change with respect to the initial equilibrium of the decentralized economy, all endogenous variables are analyzed after reaching their new long-run levels. We compare their Laffer curves and fiscal policy with a steady-state version of our optimal Laffer curve. We aim to show that there are significant differences between conventional Laffer curve calculation and the steady-state of our dynamic policy problem. Specifically, the latter does not generate as much tax revenues as the former in the long-run. The reasons why the Ramsey policy maker chooses to forgo revenues in the long-run underpins the gains from adjusting policy during the transition, which the steady-state approach ignores. We begin to explore these trade-offs in this subsection, and more fully in subsection 5.2.

We proceed as follows. We use our decentralized economy in its steady-state to reproduce Trabandt-Uhlig's labor and capital Laffer curves. A labor

Laffer curve is constructed by varying the labor tax rate and fixing consumption and capital tax rates at their calibrated values, while a capital Laffer curve is obtained by varying the capital tax rate while holding constant the other two tax rates at their calibrated values. We then compare these curves with a steady-state version of our optimal Laffer curve. The latter is constructed from the steady-state of our Ramsey model, iteratively solved by varying the initial level of debt and recovering the welfare cost implied by the associated steady-state. We plot all three curves in the welfare loss-sustainable debt space in Figure 2, where welfare costs are measured as losses of constant consumption equivalent units with respect to the decentralized economy and the sustainable debt as a percentage of GDP.[18]

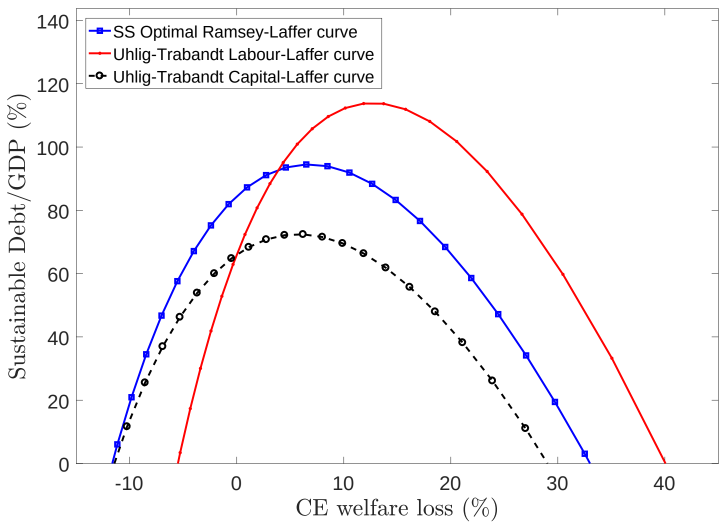

Figure 2: Comparing steady-state Laffer curves

The tallest and the lowest Laffer curves in Figure 2 are Trabandt-Uhlig's labor and capital Laffer curves, respectively, while the intermediate curve represents the steady-state version of our optimal Laffer curve. The poor performance of the capital Laffer curve reflects the well known fact that the capital tax is the most distortive tax: a policy based on increasing capital

[18]Since the level of GDP varies across policies, for comparability we refer to its level in the calibrated decentralized economy.

taxation is therefore condemned to be relatively ineffective. For this reason, we focus on Trabandt-Uhlig's labor Laffer curve for most of our comparisons. Figure 3 presents the fiscal policies underneath Trabandt-Uhlig's labor Laffer curve and the steady-state version of our optimal Laffer curve. As discussed in Section 3, optimal policy in steady-state prescribes a capital tax of zero, with labor income bearing all the burden of taxation. In contrast, Trabandt-Uhlig adopt a distortionary capital income tax of $\tau^k = 0.2$, which means that a given welfare loss is associated with a lower labor income tax as shown in the right panel of Figure 3.

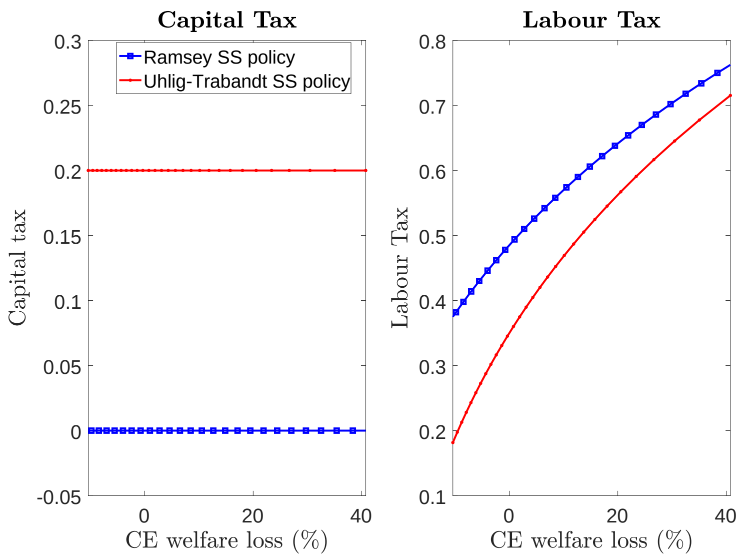

Figure 3: Comparing implied fiscal policies

The most striking implication of Figure 2 is that much of the Trabandt-Uhlig labor Laffer curve lies above the steady-state of our optimal Laffer curve. In other words, the optimizing policy maker is, in steady-state, sustaining a lower level of debt at a higher welfare cost. We now turn to explore why this is. The first point to make is that the optimal Laffer curve seeks to maximize welfare given the need to sustain a given level of debt in a dynamic economy. Therefore, the policy maker may not commit to achieving a steady-state that generates as much revenues as Trabandt-Uhlig in order to raise additional revenues during the transition at a lower welfare cost. To develop this intuition, we carry out the following analysis. Starting from the peak of the Trabandt-Uhlig Laffer curve, we move toward the optimal steady-state associated with such a point, as shown in Figure 4. In other words, we adopt a set of initial conditions implied by the peak of the Trabandt-Uhlig labor Laffer curve, and use our Ramsey problem to solve for the transitional dynamics toward the optimal steady-state these initial conditions imply. We find that such a steady-state is far from being appealing on the basis of static considerations. In particularly, the optimal long-run equilibrium is associated with a large loss of tax revenues. The sustainable debt over GDP drops from 114% to 94% with only limited long-run welfare gains. Nevertheless, when transitional dynamics are accounted for, moving toward this optimal long-run steady-state is the right thing to do. As reported in Table 2, the overall tax revenues raised are such that sustainable debt is same as the peak of Trabandt-Uhlig Laffer curve, but welfare gains are dramatic, amounting to around 9.43% in consumption equivalent units.

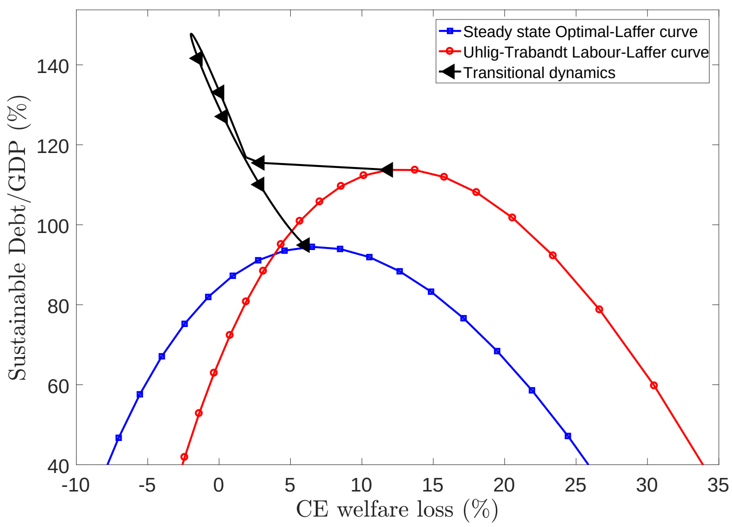

Figure 4: Transiting from Trabandt-Uhlig to Ramsey steady state

Table 2: Transition from Trabandt-Uhlig to optimal steady-state

	Capital tax	Labour tax	Debt/GDP
(1) Trabandt-Uhlig's peak	20%	49%	114%
(2) Ramsey Laffer correspondent	0%	54%	94%
Transition from (1) to (2)	4%	51%	114%
By transiting from (1) to (2) we sustain same debt but gain 9.43% CE			

The above analysis can be applied to any point of Trabandt-Uhlig's curve lying above the steady-state of our optimal Laffer curve. This implies that Trabandt-Uhlig's long-run policies are superior in terms of tax revenue raised per unit of welfare loss but only when the policy maker's ability to exploit transitional dynamics are disregarded. Trabandt-Uhlig's policies are dominated by those implied by the Ramsey model, when we include the revenues generated during the transition to the steady-state. The main implication of this result is that, if a policy maker was to announce a long-run policy on the basis of steady-state calculations, she will most likely end up choosing a highly inefficient one. It follows that focusing on steady-state calculations alone is likely to be highly misleading. The evaluation of policy changes radically when the transition is taken into account and the policy maker is able to exploit that transition.

To appreciate this better, Figure 5 contrasts our optimal Laffer curve where transitional dynamics are accounted for as previously shown in Figure 1 with its steady-state version. We link three points on our optimal Laffer curve (one from the left side, the peak and one from the right side, respectively) to their associated steady-states which correspond to specific points on the steady-state curve.[19] It can be appreciated that the points on the efficient side of the optimal Laffer curve (e.g., the curve's peak) can imply long-run equilibria falling on the slippery side of the steady-state curve. Therefore, selecting a policy on the basis of steady-state analysis alone, a government would end up disregarding a number of policy options which are in fact optimal. How costly this could be can be seen by the distance between the

[19] Recall that the steady state of our optimal policy model is dependent on the initial conditions. Each point in our optimal Laffer curve will have its own steady-state.

optimal Laffer curve and its steady-state counterpart. The policy maker can more than double the discounted value of tax revenues generated when they actively exploit transitional dynamics.

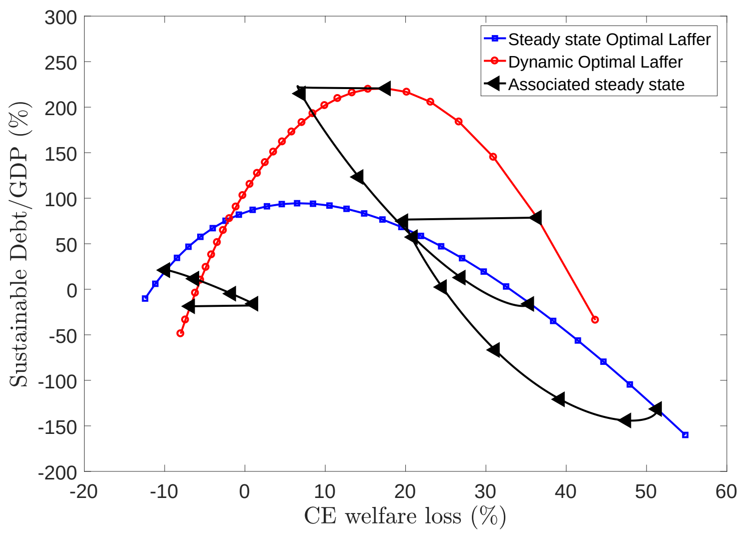

Figure 5: Optimal Laffer curve and associated steady states

5.2 Laffer Curve Comparison in Dynamic Economy

The main message of the previous section was that Laffer curve analyses should account for the potential gains from exploiting the transition to steady-state. We found that the Ramsey policy maker would not commit to the kind of static tax revenue maximizing policy implied by steady-state calculations when economic transition is accounted for. Instead they would commit to a policy mix with a less optimal steady-state since this maximizes discounted revenues generated in transition. In this subsection, we explore these transitional dynamics and the properties of the optimal tax mix. In particular, we address two issues. The first one is quantitative: how much additional fiscal revenues can be raised when the government is pursuing an optimal dynamic policy rather than adopting constant tax rates as assumed in conventional Laffer curve calculations? The second issue concerns policy design: how should an optimal fiscal policy be carried out during the economic transition?

To answer the first question, we need to account for the impact of transitional dynamics in conventional Laffer curve calculations and contrast this with the one implied by our optimal Laffer curve. Our benchmark will be the papers by D'Erasmo et al. (2015) and Mendoza et al. (2014), MTZ henceforth. MTZ construct capital and labor Laffer curves in dynamic economies which can be regarded as the dynamic counterpart of Trabandt and Uhlig (2011). Although the dynamic model enables them to account for transitional dynamics, the underlying fiscal policy assumes constant tax rates as in Trabandt and Uhlig (2011). We plot these curves with our optimal Laffer curve in Figure 6. The capital Laffer curve, again, does not facilitate the efficient generation of tax revenues. Therefore, we focus on the comparison between our optimal Laffer curve and MTZ's labor Laffer curve. The differences in these two curves are striking. At their peak, the sustainable government debt over GDP under the Ramsey policy is more than 93% higher than the constant tax rates used in MTZ. Since the peak of MTZ's labor Laffer curve and our optimal Laffer curve occur at similar welfare levels, this means that the optimal policy could greatly enhance the amount of tax revenues raised at practically no additional welfare cost. In addition, differences in debt sustainability appear to be of broadly similar magnitude everywhere along the Laffer curve measuring about 63% of GDP. By inverting this argument, it can be noted that in sustaining the same level of debt optimal policy typically offers welfare gains of about 4% in constant consumption equivalent units. Therefore, we conclude that an optimal policy has strong quantitative implications for debt sustainability, tax revenues and welfare gains.

To illustrate the second issue as to how the optimal fiscal policy underlying our optimal Laffer curve is carried out during transition, we plot the transitional dynamics associated with a particular welfare loss of 1.53% under both the optimal policy and MTZ's constant tax rates in Figure 7. We note that with the constant tax rate policy adopted by MTZ there is very limited variation in the endogenous variables during the transition. In contrast, under the Ramsey policy, capital tax rates are front-loaded and coupled with a

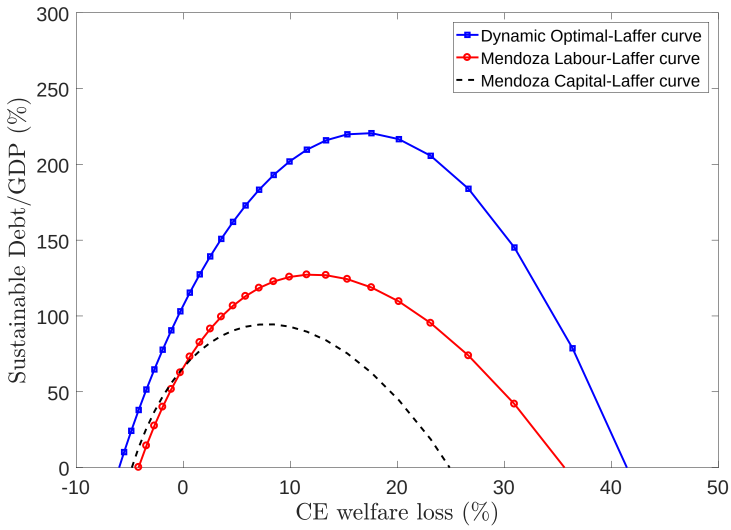

Figure 6: Comparing dynamic Laffer curves

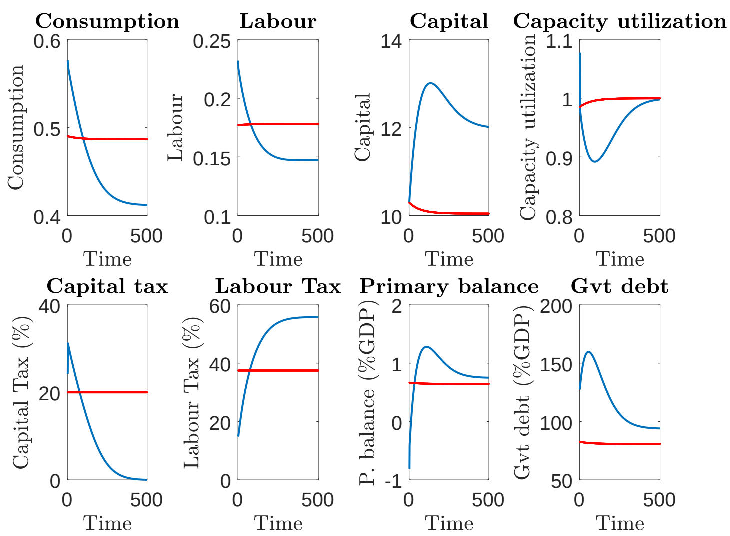

Figure 7: Transitional dynamics for CE=1.53%

complementary cut in the labor tax rate. The capital tax rate then declines until converging to zero in the steady-state, while the labor income tax rate rises consistently until achieving a relatively high long-run value. Given the commitment to abolish capital tax in the long-run and the relatively low labor taxes during the initial stages of transition, capital keeps accumulating despite it being taxed at a positive rate. This underpins the core intuition behind our optimal steady-state: the low tax revenues and the zero capital tax chosen by the Ramsey planner in the long run imply large gains during the transitional dynamics. This can be further appreciated in Figure 8 where the highest revenues are raised when both capital and labor taxes are at 'intermediate rates' and the quantity of capital has reached its maximum. Therefore, we conclude that the striking gains in revenue generation arise from a combination of the gradual erosion of capital income taxation, while at the same time increasing labor income taxation. In other words, the gains are in part due to using one tax instrument to complement another, as well as allowing tax rates to vary over time. In the following analysis, we further explore to what extent the tax revenue generated by the Ramsey policy is due to complementarity of alternative tax instruments. To do so, we only allow the Ramsey policy maker to implement one tax instrument.

We construct optimal Laffer curves for both labor and capital taxes, respectively, in each case holding other tax rates fixed at their calibrated levels. In Figure 9, we compare the labor and capital optimal Laffer curves with the corresponding steady-state Trabandt-Uhlig and dynamic MTZ Laffer curves. The left panel of Figure 9 features the labor Laffer curves. Here we see that the transitional dynamics contained within the MTZ calculation are negligible as the Trabandt-Uhlig and MTZ labor income Laffer curves are largely indistinguishable. In contrast, our optimal labor Laffer curve lies significantly above these solely as a result of the commitment to decrease and then gradually increase labor income tax. In contrast, when comparing capital tax Laffer curves plotted in the right panel, it is the MTZ and our optimal Laffer curves which are indistinguishable. This is partly because without the labor tax instrument being freely available to complement capital tax policy, capital taxes must sustain steady-state debt and cannot achieve the

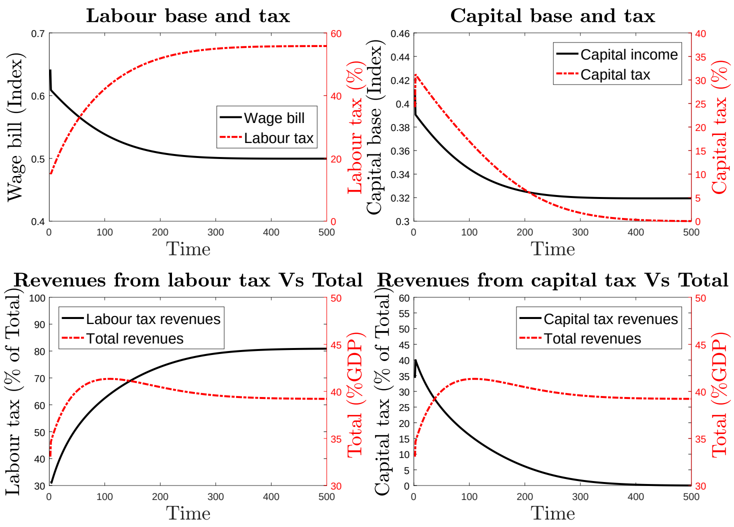

Figure 8: Optimal fiscal mix (CE=1.53%)

preferred policy of committing to reduce the capital tax rate to zero in the long-run. This brings the two forms of capital Laffer curve closer together. When comparing the labor and capital optimal Laffer curves with the optimal Laffer curve with both instruments as plotted in Figure 6 at their peak, it can be seen that two-thirds of the gains in terms of increased revenues are from gradually increasing labor tax during the transition. The other one-third comes from simultaneously eliminating capital income tax in the long-run. This finding sharply differs from the calculations of Chari et al. (1994) who find that, in a model with exogenous capacity utilization, most of the welfare gains of switching from the calibrated US fiscal policy to the Ramsey policy arise from the first period capital tax whereas labor tax plays a nearly irrelevant role. In our model with endogenous capacity utilization, the ability to exploit the capital tax of the predetermined capital stock is sharply reduced.

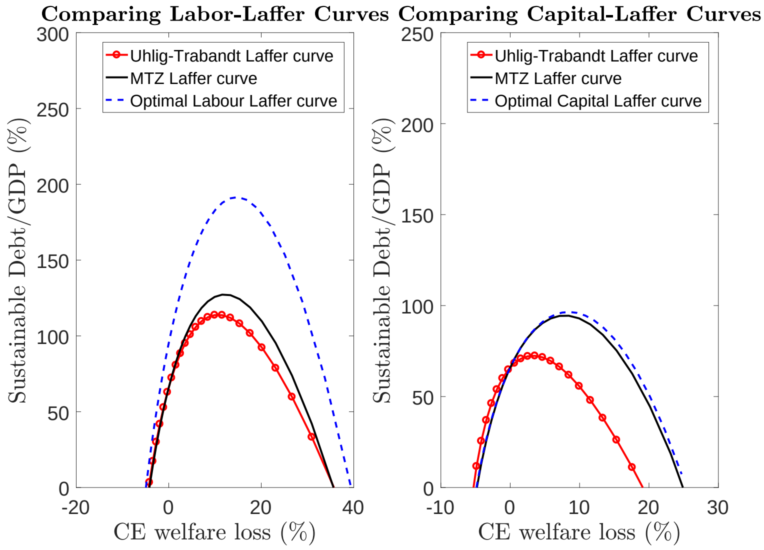

Figure 9: Comparing Trabandt-Uhlig and MTZ Laffer curves

6 Robustness and Extensions

In describing the basic properties of the Ramsey policy and optimal Laffer curve, we removed frictions such as capital adjustment costs and capital depreciation allowances. We now consider whether reintroducing such factors significantly affects the results. Following that we consider a range of extensions to the basic model. These include introducing a risk premium on sovereign debt and assuming the policy maker is myopic.

6.1 On the Role of Adjustment Costs and Depreciation Allowances

In this subsection, we consider the implication of reinstating capital adjustment costs and depreciation allowances. These features of the benchmark model were temporarily removed for analytical convenience. Capital adjustment costs imply that the capital tax base is less elastic than it otherwise would be. This means that higher tax revenues can be generated across the MTZ and optimal Laffer curves which account for transitional dynamics. On the other hand, depreciation allowance reduces the capital income tax base and tax revenues.

Figure 10 plots the MTZ and optimal Laffer curves for our benchmark model with and without adjustment costs or depreciation allowances. It is clear from the figure that the relative movements in the Laffer curves across the three types of curve are similar, such that the presence of capital adjustment costs or depreciation allowances do not affect our main results. It remains the case that the gains from conducting fiscal policy optimally dramatically increases the revenues that can be generated at a given welfare cost.

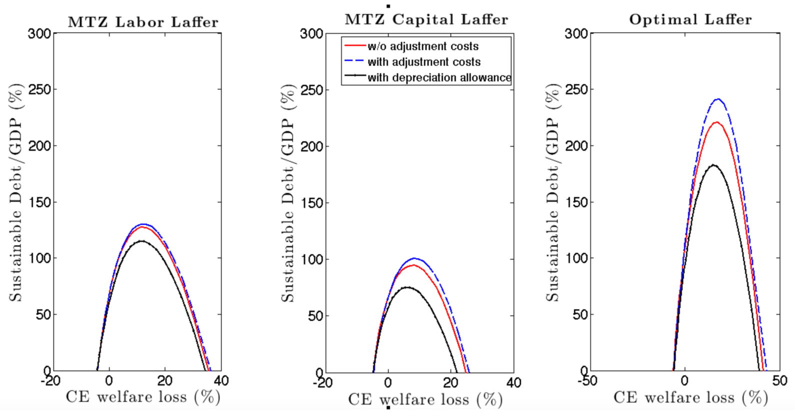

Figure 10: Comparing Laffer curves with and without adjust. costs

6.2 Risk Premia and Policy Maker Myopia

In previous sections, we have shown how the Ramsey policy can generate a significant degree of additional revenue relative to conventional approaches for assessing fiscal sustainability. We find that the gains are driven by a combination of being able to vary the labor tax over time alongside a commitment to eliminate capital taxation in the long-run. Implicitly, the prolonged transition to this time-inconsistent steady-state is entirely credible and the benevolent policy maker does not suffer any increased debt service costs when debt levels are high.

In this section, we explore the implications of relaxing these assumptions.

We do so in two ways. First, we introduce bond holding costs as a tractable way of allowing debt service costs to rise with the level of debt. This overturns the unit root in steady-state debt ensuring that the economy returns to a unique steady-state with an associated debt to GDP ratio. However, it will remain the case that in the long-run the policy maker commits to eliminate capital taxation. Secondly, we shall relax the assumption that the policy maker is fully benevolent and introduce a myopia to policy making which means they wish to delay distortionary tax increases. On its own this extension would overcome the finely balanced trade-off implied by tax smoothing and governments would be tempted to allow debt levels to rise indefinitely. When it is combined with bond holding costs there will be a unique steady-state and a non-zero long-run capital tax.

6.2.1 Risk premium

Following Heaton and Lucas (1996), we assume that there are $\Psi_t = \frac{\psi}{2}\left(d_{t+1} - \bar{d}\right)^2$ insurance costs to be paid to a financial intermediary for the household to insure the unit gross return on government bond against repayment risk. This device introduces, in a reduced form way, a risk premium on government debt which is increasing in its level. Specifically, it produces a wedge between the interest rate the government pays and the return effectively realized by the household. This feature alters the bond-pricing condition such that:

$$(1+\gamma)q_t + \psi\left(d_{t+1} - \bar{d}\right) = \widetilde{\beta}\frac{U'_{c_{t+1}}\left(c_{t+1}, 1 - l_{t+1}\right)}{U'_{c_t}\left(c_t, 1 - l_t\right)}. \tag{31}$$

We assume that the profits of these financial intermediaries are redistributed to the household in a lump-sum way.

A crucial consequence of this quadratic cost is to remove the unit root in government debt and therefore break the dependence of the model steady-state on initial conditions. In particular, in this version of the model, steady-state debt will be $d = \bar{d}/2$.[20] At the same time, the main features of the Ramsey policy (i.e. zero long-run capital income tax and bounded initial capital

[20]Debt stationarity is shown in Appendix C.4.

taxation) are preserved.[21] We calibrate $\bar{d}$ so that the long-run government debt over GDP is brought back to its pre-crisis level, i.e. $d/4y \times 100 = 66\%$. We consider this a useful reference as it implies that policy makers will seek to fully overturn increases in debt observed since 2008 and is roughly in line with the Maastricht criteria Euro-zone countries are required to meet. In addition, the parameter ψ in the function of insurance costs is related to the elasticity of interest rate to a 1% increase in debt over GDP with respect to its long-run level.[22] A recent empirical study by Laubach (2009) places this elasticity between 3 and 4 basis points while arguing that a standard RBC model tends to produce endogenously an elasticity of 2 basis points approximately. In the subsequent analysis, we then conservatively adopt a central value of 2 which corresponds to $\psi = 0.0057$.[23] Under this setting we produce an optimal Laffer curve, tracing out the relation between sustainable debt over GDP and welfare loss when risk premia are accounted for and the optimal fiscal policy is constrained to achieve a long-run equilibrium where the level of government debt is brought back to its pre-crisis level. Figure 11 plots both the MTZ labor Laffer curve and our optimal Laffer curve with bond holding costs. We can see this maintains the relative position of the two Laffer curves, and the substantial revenue gains of conducting fiscal policy optimally remains.

6.2.2 Government myopia

We further augment the risk-premium model considered above to allow for an impatient policy maker featuring higher time-discounting than the private

[21] Properties of the Ramsey policy for the extended model are derived in Appendix C.

[22] The elasticity of interest rate to a 1% increase in debt over GDP with respect to its long-run level is defined as $\eta_{r,d/4y} = \partial r / \partial \frac{d}{4y} = 4y \partial r / \partial d$, where $r \approx log\left(R\right)$ denotes the net interest rate. To see how ψ is related to $\eta_{r,d/4y}$, we first note that equation (31) in steady-state implies the following relation that $(1+\gamma)/R = \widetilde{\beta} - \psi\left(d - \bar{d}\right)$. Second, we solve for R and take logs in both side of equation (31) in steady-state. When ψ is small, we obtain the following approximation that $\partial r / \partial d = \psi / \left[\beta - \psi\left(d - \overline{d}\right)\right] \approx \psi$. Substituting this approximation into the definition of $\eta_{r,d/4y}$, gives $\eta_{r,d/4y} \approx 4y\psi$.

[23] We have also considered the cases where risk-premium elasticity is 1 or 3 basis points, and set ψ correspondingly to be 0.0028 and 0.0085. These additional results are available upon request.

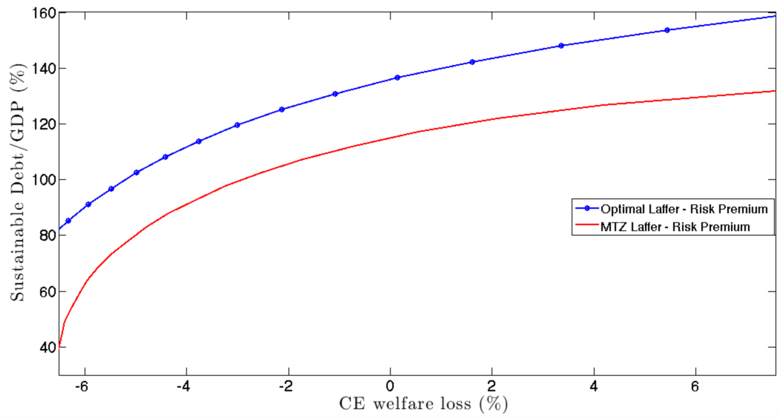

Figure 11: Comparing Laffer Curves with Risk-premium

sector. This assumption will leave our model unchanged, but in the Ramsey problem the government will discount utility at $\mu\beta$ instead of β, with $\mu < 1$ representing the gap between household and government discount factors. We can think of this as capturing the shorter horizon governments typically face relative to the private sector. More specifically, we can interpret μ as the probability of a government being in charge in the next period, and therefore $1/(1-\mu)$ is the government's expected duration. In this framework, two important characteristics of the Ramsey steady-state, the level of debt and the capital tax rate, will depend on μ, such that, both the capital tax rate and the level of debt in steady state will be increasing in the gap between government and private discounting, and therefore decreasing in μ. The myopia on the part of the government would tend to support policies which lead to an unsustainable path for debt.[24] However, in the presence of bond holding costs, this would lead to increasing debt service costs. Eventually, these rising costs more than offset the myopia of the government and the policy acts to stabilize debt. This will be at a level above $d = \bar{d}/2$ and will also result in a positive rate of capital tax in the long-run.[25]

We set μ to 0.979 such that the Ramsey steady-state will feature a cap-

[24]In essence, the myopia captures the various sources of deficit bias discussed in Alesina and Passalacqua (2016).

[25]The results of non-zero long-run capital tax rate and the level of steady-state debt are shown in Appendix C.3 and C.4, respectively.

ital income tax rate matching the decentralized economy, i.e. $\tau^k = 0.20$. The calibrated value of $\mu = 0.979$ implies an expected government duration of 12 years. This is quite an extreme assumption of the degree of myopia experienced by the government given that many of the policies governments pursue have significantly longer periods of gestation before their full benefits are realized. In addition, we keep $\overline{d}$ at the value set above. The long-run level of debt will rise to about 98.50% of GDP. We construct the optimal Laffer curve for this model and compare it with the optimal Laffer curve with the risk-premium only in Figure 12. The optimal Laffer curve produced by the model with the additional assumption of government myopia always lies beneath the one for the risk-premium alone, meaning that for the same level of government debt to be sustained, the model with myopia implies larger welfare costs. However, the marginal increase in costs due to adding myopia is relatively small at high levels of debt but larger at low levels of debt.

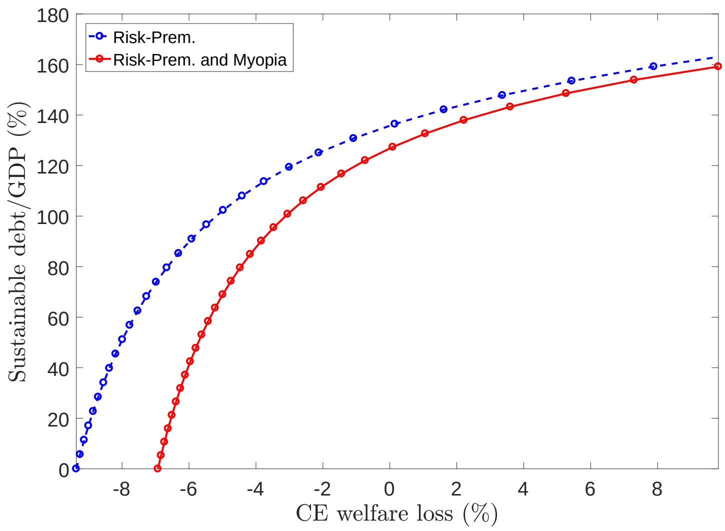

Figure 12: Comparing Laffer curves with Risk-premium and Myopia

To see why this is the case, Figure 13 plots the transitional dynamics for a number of endogenous variables at different initial debt to GDP ratios (e.g. 0%, 58% 122%). When the initial debt level is high (e.g. 122%), in the medium term, policy can still promise to reduce capital taxation to very low levels, thereby at least initially mimicking the promises inherent in the benchmark optimal Laffer curve over a more compressed time scale. In contrast, when initial debt levels are relatively low (e.g. 0% and 58%), we cannot obtain the combination of falling capital income tax rates and rising labor income tax rates, which was crucial in generating revenues by encouraging capital accumulation during the transition.

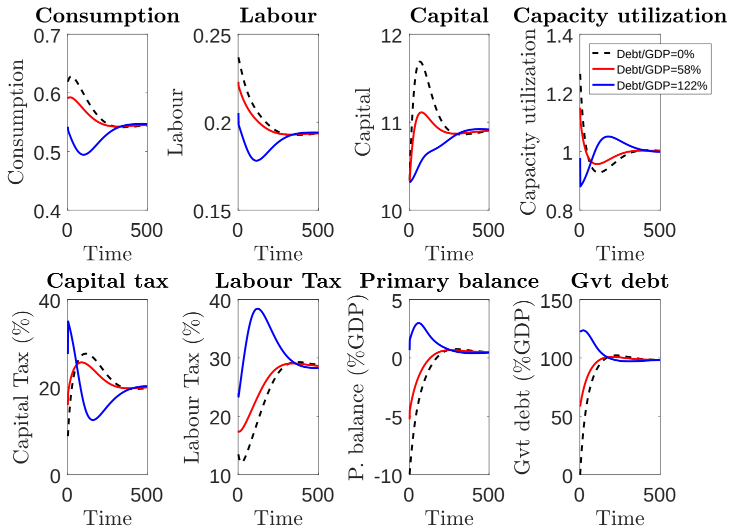

Figure 13: Myopic policies for different levels of initial debt

7 Conclusions

In the conventional Laffer curve calculations, discounted tax revenues are computed on the basis of varying individual tax instruments between 0% and 100%, while holding all other fiscal instruments constant. These studies are either carried out in a steady-state economy or a dynamic one but assume a one-off permanent change in a single tax rate.

Our paper is different from the conventional Laffer curve calculations. We plot the Laffer curve in welfare loss-sustainable debt space where the welfare loss captures the costs of the combined distortions implied by varying all tax rates optimally. As a result, each point on our Laffer curve reflects a full Ramsey problem, where the policy maker is optimally varying capital and labor income tax rates to maximize welfare given the need to satisfy the government's intertemporal budget constraint conditional on the initial level of debt. We find that, by committing to gradually eliminate capital tax and at the same time raising labor income tax, the optimal policy generates significant revenues during the economic transition. Tax revenues generated under optimal policy are up to 93% of GDP higher than those implied by the conventional Laffer curve calculations. However, this also assumed that the fiscal authority is fully credible and benevolent, and it does not suffer any increased debt service costs when debt levels are high.

Therefore, in a subsequent robustness analysis, we enrich the model by allowing debt service costs to rise with debt levels. This reduces the sustainable debt levels achievable by both the conventional and our optimal Laffer curves, but does not overturn the conclusion that there remain significant gains either in terms of revenues raised or welfare costs from conducting fiscal policy optimally. In addition, we further allow for a significant degree of policy maker myopia. Although the model with myopia implies larger welfare costs than the one with debt service costs only, the marginal increase in costs due to adding myopia is relatively small, especially at high levels of debt.

To sum up, our analysis suggests that conventional approaches to computing Laffer curves can significantly underestimate the amount of tax revenues that can be potentially generated or, equivalently, overstate the welfare costs of achieving a given level of fiscal revenues. In the future research, we will explore the degree to which time-inconsistency problem affects the revenue generating powers of a policy maker.

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Appendix

A The Decentralized Economy

The equilibrium conditions of the decentralized economy are summarized below. We remove capital adjustment costs and capital depreciation allowances (i.e. $\eta = 0$ and $\theta = 0$) and fix the consumption tax rate, τ_t^c, at a calibrated value consistent with the data, $\tau_t^c = \tau^c$. This is to facilitate the derivation of the primal form of our Ramsey problem.

$$(1+\gamma)q_t = \widetilde{\beta}\frac{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)}{U'_{c_t}\left(c_t, 1-l_t\right)}, \tag{A1}$$

$$-\frac{U'_{l_t}\left(c_t, 1-l_t\right)}{U'_{c_t}\left(c_t, 1-l_t\right)} = \frac{1-\tau_t^l}{1+\tau^c}w_t, \tag{A2}$$

$$U'_{c_t}\left(c_t, 1-l_t\right) = \frac{\widetilde{\beta}}{1+\gamma}U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)\left[\begin{array}{c} 1-\delta(m_{t+1}) \\ +(1-\tau_{t+1}^k)r_{t+1}m_{t+1} \end{array}\right], \tag{A3}$$

$$(1-\tau_t^k)r_t = \delta'_{m_t}(m_t), \tag{A4}$$

$$F'_{s_t}(s_t, l_t) = r_t, \tag{A5}$$

$$F'_{l_t}(s_t, l_t) = w_t, \tag{A6}$$

$$F(s_t, l_t) = c_t + g_t + (1+\gamma)k_{t+1} - \left[1-\delta(m_t)\right]k_t \tag{A7}$$

$$m_t k_t = s_t, \tag{A8}$$

$$g_t = \overline{g}, \tag{A9}$$

$$e_t = \overline{e}. \tag{A10}$$

B The Primal Form of the Baseline Model

In this section, we present the primal form for the baseline model. Before showing how the Lagrangian function of the primal form is constructed, we first detail the derivation of the implementability constraint. The derivation of the other three constraints (i.e. the resource constraint, the capital utilization constraint, and the period-0 capital utilization condition) is illustrated in Section 3 of the maintext.

B.1 The Implementability Constraint

To derive the implementability constraint, we start with the household's budget constraint,

$$(1+\tau^c)c_t+(1+\gamma)q_t d_{t+1}+(1+\gamma)k_{t+1} = (1-\tau^l)w_t l_t+(1-\tau_t^k)r_t m_t k_t+[1-\delta(m_t)]\,k_t+d_t+\overline{e}. \tag{B1}$$

In addition, to simplify the notation below, we define

$$z_t \equiv (1+\tau^c)c_t - (1-\tau_t^l)w_t l_t, \tag{B2}$$

$$R_t^K \equiv \left(1-\tau_t^k\right) r_t m_t + 1 - \delta\left(m_t\right), \tag{B3}$$

and substitute the Euler equation (A1) into the above household budget constraint in (B1) to obtain

$$d_t = z_t + (1+\gamma)k_{t+1} - R_t^K k_t - \overline{e} + \widetilde{\beta}\frac{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)}{U'_{c_t}\left(c_t, 1-l_t\right)} d_{t+1}, \tag{B4}$$

The corresponding expression in period-0 reads

$$d_0 = z_0 + (1+\gamma)\,k_1 - R_0^K k_0 - \overline{e} + \widetilde{\beta}\frac{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)}{U'_{c_0}\left(c_0, 1-l_0\right)} d_1. \tag{B5}$$

We then substitute for all $d_{t\geqslant 1}$ recursively in equation (B5). The transversality conditions $\lim_{t\to\infty}\widetilde{\beta}^{t+1}U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)d_{t+1} = 0$ and $\lim_{t\to\infty}\widetilde{\beta}^{t}U'_{c_t}\left(c_t, 1-l_t\right)$ $k_{t+1} = 0$, and the first order condition (A3) imply that the consolidated budget constraint at period-0 can be simplified to

$$d_0 + R_0^K k_0 = \sum_{t=0}^{\infty} \widetilde{\beta}^t \frac{U'_{c_t}(c_t, 1-l_t)}{U'_{c_0}(c_0, 1-l_0)} (z_t - \overline{e}) \tag{B6}$$

Finally, we substitute expression (B2) and (B3) back in (B6), and use the intratemporal consumption-leisure margin in (A2) to substitute out the labor tax. Therefore we obtain the implementability constraint,

$$B - \sum_{t=0}^{\infty} \widetilde{\beta}^t \left[U'_{c_t}(c_t, 1-l_t) \left(c_t - \frac{\overline{e}}{(1+\tau^c)} \right) + U'_{l_t}(c_t, 1-l_t)\, l_t \right] = 0,$$

where

$$B \equiv \left\{ d_0 + \left[\left(1-\tau_0^k\right) r_0 m_0 + 1 - \delta(m_0) \right] k_0 \right\} \frac{U'_{c_0}(c_0, 1-l_0)}{1+\tau^c}$$

collects the period-0 terms.

The implementability constraint, the resource constraint, the capital utilization constraint, and the period-0 capital utilization condition are the four constraints in the primal form of the Ramsey problem for our baseline model. In the next subsection we derive the Lagrangian function of the primal form presented in Section 3.

B.2 Ramsey Problem in the Primal Form

The Ramsey problem in primal form consists of maximizing the utility function,

$$\sum_{t=0}^{\infty} \widetilde{\beta}^t U(c_t, 1-l_t),$$

subject to four contraints. These are the resource constraint

$$F(m_t k_t, l_t) - c_t - g_t - (1+\gamma) k_{t+1} + [1-\delta(m_t)]\, k_t \geq 0,$$

the implementability constraint

$$B-\sum_{t=0}^{\infty}\widetilde{\beta}^{t}\left[U_{c_t}'\left(c_t,1-l_t\right)\left(c_t-\frac{\overline{e}}{1+\tau^{c}}\right)+U_{l_t}'\left(c_t,1-l_t\right)l_t\right]\geq 0,$$

the capital utilization constraint for $t>0$

$$\frac{U_{c_t}'\left(c_t,1-l_t\right)}{U_{c_{t+1}}'\left(c_{t+1},1-l_{t+1}\right)}=\frac{\widetilde{\beta}}{1+\gamma}\left[\delta_{m_{t+1}}'(m_{t+1})m_{t+1}+1-\delta(m_{t+1})\right],$$

and the period-0 capital utilization condition,

$$\left(1-\tau_0^{k}\right)F_{s_0}'(m_0k_0,l_0)=\delta_{m_0}'\left(m_0\right).$$

The Lagrangian function of the primal form is then constructed as follows

$$\max_{\{c_t,l_t,m_t,k_{t+1},\tau_0^k\}_{t=0}^{\infty}} R=$$

$$\sum_{t=0}^{\infty}\widetilde{\beta}^{t}\left\{\begin{array}{c}U\left(c_t,1-l_t\right)\\ +\phi\left\{B-\left[U_{c_t}'\left(c_t,1-l_t\right)\left(c_t-\frac{\overline{e}}{1+\tau^{c}}\right)+U_{l_t}'\left(c_t,1-l_t\right)l_t\right]\right\}\\ +\lambda_t^{1}\left[\left(\frac{1+\gamma}{\widetilde{\beta}}\right)\frac{U_{c_t}'(c_t,1-l_t)}{U_{c_{t+1}}'(c_{t+1},1-l_{t+1})}-\delta_{m_{t+1}}'(m_{t+1})m_{t+1}-1+\delta(m_{t+1})\right]\\ +\lambda_t^{2}\left[F(m_tk_t,l_t)-c_t-\overline{g}-(1+\gamma)k_{t+1}+\left(1-\delta(m_t)\right)k_t\right]\\ +\varphi\left[\left(1-\tau_0^{k}\right)F_{s_0}'(m_0k_0,l_0)-\delta_{m_0}'\left(m_0\right)\right]\end{array}\right\},\tag{B7}$$

where ϕ, λ_t^1, λ_t^2 and φ are the four multipliers attached to the resource constraint, the implementability constraint, the capital utilization constraint, and the period-0 capital utilization condition, respectively.

By grouping all terms in (B7) containing the utility function, we define the objective function as

$$\begin{aligned}V(c_t,1-l_t,\phi,\lambda_t^1) \;=\;& U\left(c_t,1-l_t\right)\\ &+\phi\left[U_{c_t}'\left(c_t,1-l_t\right)\left(c_t-\frac{\overline{e}}{1+\tau^{c}}\right)+U_{l_t}'\left(c_t,1-l_t\right)l_t\right]\\ &+\lambda_t^{1}\left[\left(\frac{1+\gamma}{\widetilde{\beta}}\right)\frac{U_{c_t}'\left(c_t,1-l_t\right)}{U_{c_{t+1}}'\left(c_{t+1},1-l_{t+1}\right)}\right],\end{aligned}$$

the above Lagrangian function can be then rewritten as follows,

$$\max_{\{c_t,l_t,m_t,k_{t+1},\tau_0^k\}_{t=0}^{\infty}} R =$$
$$\sum_{t=0}^{\infty}\widetilde{\beta}^t \left\{ \begin{array}{c} V(c_t,1-l_t,\phi,\lambda_t^1) \\ -\lambda_t^1\left[\delta'_{m_{t+1}}(m_{t+1})m_{t+1}+1-\delta(m_{t+1})\right] \\ +\lambda_t^2\left[F(m_tk_t,l_t)-c_t-\overline{g}-(1+\gamma)k_{t+1}+(1-\delta(m_t))\,k_t\right] \end{array} \right\} \quad \text{(B8)}$$
$$-\phi\left\{B-\frac{\varphi}{\phi}\left[\left(1-\tau_0^k\right)F'_{s_0}(m_0k_0,l_0)-\delta'_{m_0}(m_0)\right]\right\}$$

Where

$$A \equiv B-\frac{\varphi}{\phi}\left[\left(1-\tau_0^k\right)F'_{s_0}(m_0k_0,l_0)-\delta'_{m_0}(m_0)\right].$$

captures all period-0 constraints including B in the implementability constraint and the period-0 capital utilization condition. In Section 3, we present the Lagrangian function in (B8).

C The Primal Form of the Extended Model

This section derives the primal form for our extended model in Section 6. Due to the presence of risk premium on government bond, households pay an insurance, $\Psi_t = \frac{\psi}{2}\left(d_{t+1}-\overline{d}\right)^2$, to a financial intermediary to secure a unit return on government bond against repayment risk. In addition, the profits of such as a financial institution, ϵ_t, are redistributed to households in a lump-sum way. Therefore, the household budget constraint is modified as follows,

$$\begin{aligned} & (1+\tau^c)c_t+(1+\gamma)q_td_{t+1}+(1+\gamma)k_{t+1}+\Psi_t \\ = \; & (1-\tau^l)w_tl_t+(1-\tau_t^k)r_tm_tk_t+\left[1-\delta(m_t)\right]k_t+d_t+\overline{e}+\epsilon_t. \end{aligned}$$

Since the financial intermediary has zero marginal and fixed costs, $\Psi_t = \epsilon_t$ holds in equilibrium. In addition, the Euler equation (A1) is modified to incorporate the insurance costs as follows,

$$(1+\gamma)q_t + \psi\left(d_{t+1} - \bar{d}\right) = \widetilde{\beta}\frac{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)}{U'_{c_t}\left(c_t, 1-l_t\right)}. \tag{C1}$$

Therefore, the presence of insurance costs alters the implementability constraint derived above, while the other constraints (i.e. the resource constraint and the capital utilization constraint) remain the same as in the baseline model.

In the following subsections, we derive the new implementability constraint for our model with risk premium, and then we will show the Lagrangian function of the primal form Ramsey problem with both risk premium and government myopia.

C.1 The Implementability Constraint with Risk Premia

By substituting the new Euler equation in (C1) into the household budget constraint, we get:

$$\begin{aligned}&(1+\tau^c)c_t - \psi\left(d_{t+1} - \bar{d}\right)d_{t+1} + \widetilde{\beta}\frac{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)}{U'_{c_t}\left(c_t, 1-l_t\right)}d_{t+1} + (1+\gamma)k_{t+1} = \\ &(1-\tau^l)w_t l_t + (1-\tau_t^k)r_t m_t k_t + \left[1-\delta(m_t)\right]k_t + d_t + \overline{e}.\end{aligned} \tag{C2}$$

We then rearrange equation (C2) as follows

$$\begin{aligned}d_t = \quad & z_t - \psi\left(d_{t+1} - \bar{d}\right)d_{t+1} + (1+\gamma)k_{t+1} - R_t^K k_t - \overline{e} \\ & + \widetilde{\beta}\frac{U'_{c_{t+1}}\left(c_{t+1}, 1-l_{t+1}\right)}{U'_{c_t}\left(c_t, 1-l_t\right)}d_{t+1},\end{aligned} \tag{C3}$$

where z_t and R_t^K are defined as in equations (B2) and (B3).

The corresponding consolidated budget constraint at period-0 is given by

$$d_0 + R_0^K k_0 = \sum_{t=0}^{\infty} \widetilde{\beta}^t \frac{U'_{c_t}\left(c_t, 1-l_t\right)}{U'_{c_0}\left(c_0, 1-l_0\right)} \begin{bmatrix} z_t - \overline{e} \\ -\psi\left(d_{t+1} - \bar{d}\right)d_{t+1} \end{bmatrix}.$$

Differently from the baseline model, the government debt that describes the risk premium cannot be easily substituted away. This implies that we cannot discard the sequence of budget constraints for periods $t = 1, 2, 3, ...,$ after consolidating at period-0. Therefore, we have a sequence of implementability constraints for all periods $t \geq 0$ for the extended model.

$$d_t + R_t^K k_t = \sum_{j=0}^{\infty} \widetilde{\beta}^j \frac{U'_{c_{t+j}}\left(c_{t+j}, 1 - l_{t+j}\right)}{U'_{c_t}\left(c_t, 1 - l_t\right)} \left[\begin{array}{c} z_{t+j} - \overline{e} \\ -\psi\left(d_{t+j+1} - \bar{d}\right) d_{t+j+1} \end{array} \right]. \quad \text{(C4)}$$

Finally, we substitute the intratemporal consumption-leisure margin in (A2), the capacity utilization condition (A4) and expression (B2) and (B3) into the sequence of consolidated budget constraints in (C4), we get the implementability constraint for period t as follows,

$$\left\{d_t + \left[\delta'_{m_t}(m_t)m_t + 1 - \delta\left(m_t\right)\right] k_t\right\} \frac{U'_{c_t}\left(c_t, 1 - l_t\right)}{1 + \tau^c} = \sum_{j=0}^{\infty} \widetilde{\beta}^j \Big\{U'_{c_{t+j}}\left(c_{t+j}, 1 - l_{t+j}\right) \times$$
$$\left[c_{t+j} - \frac{\psi\left(d_{t+j+1} - \bar{d}\right) d_{t+j+1}}{1 + \tau^c} - \frac{\overline{e}}{1 + \tau^c}\right] + U'_{l_{t+j}}\left(c_{t+j}, 1 - l_{t+j}\right) l_{t+j}\Big\}. \quad \text{(C5)}$$

C.2 Ramsey Problem with Risk-premium and Myopia in the Primal Form

This subsection outlines the Lagrangian function for the primal form Ramsey problem with risk premium and myopia. In the latter case, the government will discount utility at $\mu\widetilde{\beta}$, instead of $\widetilde{\beta}$, with $\mu < 1$ representing the gap between household and government discount factors. In addition, the presence of a sequence of implementability constraints in (C5) for all $t \geqslant 0$ complicates the setup of the Lagrangian function of this problem. In order to write the Lagrangian function in a compact form, we follow Aiyagari et al. (2002) and Rieth (2017) in defining a recursive multiplier, $\lambda_t^3 = \frac{\lambda_{t-1}^3}{\mu} + \upsilon_t$, with $\lambda_{-1}^3 = 0$, to be attached to the implementability constraint in (C5).

Therefore, the Lagrangian function is constructed as follow,

$$\max_{\{c_t,l_t,m_t,k_{t+1},d_{t+1}\}_{t=0}^{\infty}} R =$$

$$\sum_{t=0}^{\infty}\left(\mu\widetilde{\beta}\right)^t \left\{ \begin{array}{c} U\left(c_t, 1-l_t\right) \\ +\lambda_t^1\left[\left(\frac{1+\gamma}{\widetilde{\beta}}\right)\frac{U'_{c_t}(c_t,1-l_t)}{U'_{c_{t+1}}(c_{t+1},1-l_{t+1})} - \delta'_{m_{t+1}}(m_{t+1})m_{t+1} - 1 + \delta(m_{t+1})\right] \\ +\lambda_t^2\left[F(m_t k_t, l_t) - c_t - \overline{g} - (1+\gamma)k_{t+1} + (1-\delta(m_t))\,k_t\right] \\ +\lambda_t^3\left\{U'_{c_t}\left(c_t, 1-l_t\right)\left[c_t - \frac{\psi\left(d_{t+1}-\bar{d}\right)d_{t+1}}{1+\tau^c} - \frac{\bar{e}}{1+\tau^c}\right] + U'_{l_t}\left(c_t, 1-l_t\right)l_t\right\} \\ -\upsilon_t\left\{\left[d_t + \left[\delta'_{m_t}(m_t)m_t + 1 - \delta\left(m_t\right)\right]k_t\right]\frac{U'_{c_t}(c_t,1-l_t)}{1+\tau^c}\right\} \end{array} \right\}, \tag{C6}$$

where λ_t^1 and λ_t^2 again, are multipliers associated with the resource constraint and the capital utilization constraint. It is important to clarify that the period-0 capital utilization condition now is embeded in the new the implementability constraint for the extended model.

The first order conditions for $t \geq 0$ are:

$$\{c_t\}: \quad \lambda_t^2 - U'_{c_t}\left(c_t, 1-l_t\right) - \lambda_t^3 U'_{c_t}\left(c_t, 1-l_t\right) - \lambda_t^3 U''_{l_t c_t}\left(c_t, 1-l_t\right)l_t =$$

$$\left\{ \begin{array}{c} -\lambda_{t-1}^1\frac{(1+\gamma)U'_{c_{t-1}}(c_{t-1},1-l_{t-1})}{\mu\widetilde{\beta}^2 U'_{c_t}(c_t,1-l_t)^2} \\ +\lambda_t^1\frac{1+\gamma}{\widetilde{\beta}U'_{c_{t+1}}(c_{t+1},1-l_{t+1})} \\ +\lambda_t^3\left[c_t - \frac{\psi\left(d_{t+1}-\bar{d}\right)d_{t+1}}{1+\tau^c} - \frac{\bar{e}}{1+\tau^c}\right] \\ -\frac{\upsilon_t}{1+\tau^c}\left[d_t + \left[\delta'_{m_t}\left(m_t\right)m_t + 1 - \delta\left(m_t\right)\right]k_t\right] \end{array} \right\} U''_{c_t}\left(c_t, 1-l_t\right), \tag{C7}$$

$$\{l_t\}: \quad -\lambda_t^2 F'_{l_t}(m_t k_t, l_t) - U'_{l_t}(c_t, 1-l_t) - \lambda_t^3 U'_{l_t}(c_t, 1-l_t) - \lambda_t^3 U''_{l_t}(c_t, 1-l_t)\, l_t =$$

$$\left\{ \begin{array}{c} \lambda_{t-1}^1 \frac{(1+\gamma) U'_{c_{t-1}}(c_{t-1}, 1-l_{t-1})}{\mu \widetilde{\beta}^2 U'_{c_t}(c_t, 1-l_t)^2} \\ +\lambda_t^1 \frac{1+\gamma}{\widetilde{\beta} U'_{c_{t+1}}(c_{t+1}, 1-l_{t+1})} \\ +\lambda_t^3 \left[c_t - \frac{\psi\left(d_{t+1} - \bar{d}\right) d_{t+1}}{1+\tau^c} - \frac{\bar{e}}{1+\tau^c} \right] \\ -\frac{\upsilon_t}{1+\tau^c} \left[d_t + \left[\delta'_{m_t}(m_t)\, m_t + 1 - \delta(m_t) \right] k_t \right] \end{array} \right\} U''_{c_t l_t}(c_t, 1-l_t), \tag{C8}$$

$$\begin{aligned} \{m_t\}: \quad & \lambda_{t-1}^1 \delta''_{m_t}(m_t) m_t = -\mu \widetilde{\beta} \upsilon_t \delta''_{m_t}(m_t)\, m_t k_t \frac{U'_{c_t}(c_t, 1-l_t)}{1+\tau^c} + \\ & \mu \widetilde{\beta} \lambda_t^2 \left[F'_{m_t}(m_t k_t, l_t) - \delta'_{m_t}(m_t) \right] k_t, \end{aligned} \tag{C9}$$

$$\begin{aligned} \{k_{t+1}\}: \quad & \lambda_t^2 (1+\gamma) = \mu \widetilde{\beta} \lambda_{t+1}^2 \left[\; F'_{k_{t+1}}(m_{t+1} k_{t+1}, l_{t+1}) m_{t+1} + 1 - \delta(m_{t+1}) \; \right] \\ & - \mu \widetilde{\beta} \upsilon_{t+1} \left[\delta'_{m_{t+1}}(m_{t+1})\, m_{t+1} + 1 - \delta(m_{t+1}) \right] \frac{U'_{c_{t+1}}(c_{t+1}, 1-l_{t+1})}{1+\tau^c}, \end{aligned} \tag{C10}$$

$$\{d_{t+1}\}: \quad \mu \widetilde{\beta} \upsilon_{t+1} \frac{U'_{c_{t+1}}(c_{t+1}, 1-l_{t+1})}{1+\tau^c} = \lambda_t^3 \frac{U'_{c_t}(c_t, 1-l_t)}{1+\tau^c} \left(\psi \bar{d} - 2\psi d_{t+1} \right), \tag{C11}$$

$$\begin{aligned} \{c_0\}: \quad & \lambda_0^2 - U'_{c_0}(c_0, 1-l_0) - \lambda_t^3 U'_{c_0}(c_0, 1-l_0) - \lambda_t^3 U''_{l_0 c_0}(c_0, 1-l_0)\, l_0 \\ & = \left\{ \begin{array}{c} \lambda_0^1 \frac{1+\gamma}{\widetilde{\beta} U'_{c_1}(c_1, 1-l_1)} \\ +\lambda_t^3 \left[c_0 - \frac{\psi\left(d_1 - \bar{d}\right) d_1}{1+\tau^c} - \frac{\bar{e}}{1+\tau^c} \right] \\ -\frac{\upsilon_0}{1+\tau^c} \left[d_0 + \left[\delta'_{m_0}(m_0) m_0 + 1 - \delta(m_0) \right] k_0 \right] \end{array} \right\} U''_{c_0}(c_0, 1-l_0) \end{aligned} \tag{C12}$$

$$\{l_0\}: \quad -\lambda_0^2 F'_{l_0}(m_0 k_0, l_0) - U'_{l_0}(c_0, 1-l_0) - \lambda_0^3 U'_{l_0}(c_0, 1-l_0) - \lambda_0^3 U''_{l_0}(c_0, 1-l_0)\, l_0$$
$$= \left\{ \begin{array}{c} \lambda_0^1 \frac{(1+\gamma)}{\widetilde{\beta} U'_{c_1}(c_1, 1-l_1)} \\ +\lambda_0^3 \left[c_0 - \frac{\psi\left(d_1 - \bar{d}\right) d_1}{1+\tau^c} - \frac{\bar{e}}{1+\tau^c} \right] \\ -\frac{v_0}{1+\tau^c} \left[d_0 + \left[\delta'_{m_0}(m_0) m_0 + 1 - \delta\left(m_0\right) \right] k_0 \right] \end{array} \right\} U''_{c_0 l_0}(c_0, 1-l_0) \tag{C13}$$

$$\{m_0\}: \quad \mu \widetilde{\beta} v_0 \delta''_{m_0}(m_0)\, m_0 \frac{U'_{c_t}(c_t, 1-l_t)}{1+\tau^c} = \mu \widetilde{\beta} \lambda_0^2 \left[F'_{m_0}(m_0 k_0, l_0) - \delta'_{m_0}(m_0) \right], \tag{C14}$$

The above set of first order conditions (C7)-(C14) and the three contraints characterize the solution of Ramsey problem for the extended model.

C.3 Non-zero Long-run capital tax

Introducing risk premium does not alter the zero long-run capital tax result in the baseline model. However, when allowing for policy myopia, the long-run capital tax becomes positive and increasing in the degree of myopia. In this subsection, we show how the two extensions of the model affect the long-run first order condition with respect to capital.

We first substitute v and $\delta'_m(m)$ in the long-run Ramsey first order condition with respect to capital (C10), using the steady-state multiplier of the implementability constraint and capacity utilization condition to obtain,

$$\begin{aligned} &\lambda^2(1+\gamma) = \mu \widetilde{\beta} \lambda^2 \left[F'_k(mk, l) m + 1 - \delta(m) \right] \\ &+ (1-\mu) \widetilde{\beta} \lambda^3 \left[(1-\tau^k) F'_k(mk, l) m + 1 - \delta(m) \right] \frac{U'_c(c, 1-l)}{1+\tau^c} \end{aligned} \tag{C15}$$

Given that the Ramsey allocation is a competitive equilibrium, combining equation (C15) and the long-run intertemporal investment decision under the competitive equilibrium,

$$\widetilde{\beta}\left[(1-\tau^k)F'_k(mk,l)m+1-\delta(m)\right]=1+\gamma,$$

we obtain the following expression for the Ramsey capital tax in the long-run:

$$\tau^k=\frac{(1-\mu)\left[\lambda^2-\lambda^3\frac{U'_c(c,1-l)}{1+\tau^c}\right]\left[F'_k(mk,l)m+1-\delta\left(m\right)\right]}{\left[\lambda^2-\left(1-\mu\right)\lambda^3\frac{U'_c(c,1-l)}{1+\tau^c}\right]F'_k(mk,l)m}. \tag{C16}$$

In the absence of myopia, $\mu=1$, the Ramsey capital tax, τ^k, is zero in the long-run, which is consistent with the baseline model. However, under the assumption of policy myopia, $\mu<1$, to further show that the Ramsey capital tax is positive, we need to show that $\lambda^2>\lambda^3\frac{U'_c(c,1-l)}{1+\tau^c}$, which is difficult to show analytically, but does hold for our benchmark calibration and any other permutation of parameters we have tried.

C.4 Debt stationarity

In the extended model, government debt is no longer a unit root process; instead it will be mean-revering in the long-run. We show below this is the case.

The steady-state Ramsey first order condition with respect to debt in (C11) is

$$d=\frac{\widetilde{\beta}\left(1-\mu\right)}{2\psi}+\frac{\bar{d}}{2},$$

which implies that without myopia, $\mu=1$, Ramsey policy will prescribe $d=\frac{\bar{d}}{2}$. However, under the assumption of government myopia, $\mu<1$, $d>\frac{\bar{d}}{2}$ and increasing in the degree of Myopia. In both cases, the Ramsey solution implies a unique long-run level of debt independent from the initial conditions.

C.5 Bounded period-0 capital tax

In the extended model, the trade-off in the period-0 capital tax optimality condition remains qualitatively unchanged, when choosing the period-0 capital tax, the government will still trade-off the benefit of reducing debt burden versus the cost of household reducing capacity utilization.

D Measuring Welfare Costs

In our Laffer curve calculations welfare associated with alternative fiscal policies (and revenues) are computed in equivalent constant consumption units as in Schmitt-Grohé and Uribe (2007). This procedure is a natural way for quantitatively comparing welfare across alternative policies when the utility function does not support a cardinal interpretation. We briefly outline the procedure below. Consider two alternative policy regimes A and B, we define life-time welfare as:

$$W^A = E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t U\left(c_t^A, 1 - l_t^A\right) \tag{D1}$$

and

$$W^B = E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t U\left(c_t^B, 1 - l_t^B\right) \tag{D2}$$

Let us denote λ^c the welfare cost of adopting the policy regimes B in place of the policy regimes A in terms of constant consumption units. Then λ^c would be implicitly defined as:

$$W^B = E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t U\left(\left(1 - \lambda^c\right) c_t^A, 1 - l_t^A\right) \tag{D3}$$

For the utility function we employ the above expression can be re-written as:

$$W^B = E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \frac{\left[\left(1 - \lambda^c\right) c_t^A \left(1 - l_t^A\right)^a\right]^{1-\sigma}}{1 - \sigma} = \frac{\left(1 - \lambda^c\right)^{1-\sigma}}{1 - \sigma} W^A \tag{D4}$$

and solving for λ^c we obtain:

$$\lambda^c = 1 - \left[\frac{W^B}{W^A}(1-\sigma)\right]^{\frac{1}{1-\sigma}} \tag{D5}$$