

An Evaluation of the Revenue side as a source of fiscal consolidation in high debt economies

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Abstract

Unsustainable levels of debt for some European economies is causing enormous strain in the Euro area. How to tide over the debt crisis seems to be the most important objective the European policy makers are currently facing. We use a dynamic general equilibrium closed economy model to compute the dynamic Laffer Curves for Portugal, Ireland, Greece and Spain for different class of taxes. We conclude that there exists scope for considerable revenue generation by raising certain class of taxes. Thus revenue generation, along with fiscal consolidation holds key for debt reduction.

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1 Introduction

As Greece was aided by IMF and EU with a massive bailout package in June 2011, conditioned on some stringent austerity measures, tension mounted on the streets of Athens. The lenders however sought even greater interest for Greek debt and as credit rating agencies downgraded the credit rating for Greece several times in quick succession, a sovereign default seemed inevitable. In November 2011 however European leaders got the banks to take a 50 per cent loss on the face value of Greek debt. This measure is set to bring modest success as Greek public debt is projected to reduce to 120 per cent of GDP by 2020. Presently the policy makers of the beleaguered economy is pushing through further painful structural reforms in order to secure a second bail out from the European Union members. Despite staving off immediate crisis, the critical question that the policy makers face is how to reduce debt in a successful and sustainable way in the longer horizon for the four high debt European economies - Portugal, Ireland, Greece and Spain.

The conventional wisdom for fiscal consolidation is expenditure cuts. In this paper I argue that in addition to the received wisdom of fiscal consolidation through expenditure cuts, revenue generation through an increase in certain class of tax rates should also be considered. I compute the dynamic Laffer curves for the four economies by calibrating a flex-price Cass-Koopmans style model and show that there exists some room for tax maneuverability. The rest of the paper is organized as follows. Section 2 discusses major lessons from successful debt reductions in the past. Section 3 talks about the present debt crisis and how it evolved through the decade. Section 4 lays out the model and the calibration details and section 5 discusses the main results.

2 Lessons from past successful debt reductions

Historically successful debt reduction strategies as analyzed by [Nickel et al. \[2010\]](#) can be characterized into two main classes. One, robust macroeconomic environments help economies “grow out of debt” in the long run and two, the economies work towards maintaining primary budget surpluses through decisive and lasting fiscal consolidation efforts. This long term fiscal consolidation efforts focus on decreasing government expenditure through cuts on welfare benefits and public wage spending. They argue that the past experiences of successful debt reduction. For instance in Denmark public debt was reduced from 80 per cent in 1994 to 26.8 per cent in 2007 with an overall change in debt ratio of 53%. In Ireland public debt ratio reduced from 94% of GDP in 1994 to 24.9% in 2004; even Portugal and Spain reduced debt by 10% and 30% respectively. One of the lessons which emerge from past experience is that successful debt reduction is almost a result of sustained effort. Also evidence suggests that expenditure based methods have been more successful than revenue based methods so far as reducing debt

is concerned. Fiscal adjustments through spending cuts on transfers and government wage bill was also favored by [Alesina and Perotti \[1996\]](#) to that by tax increases. This finding is subsequently reconfirmed by [Alesina and Ardagna \[2009\]](#) with data from 1970-2007.

However one must note that it is often empirically impossible to clearly identify the underlying policy changes as most expenditure cut induced fiscal consolidation has been accompanied by structural reforms. The structural reforms often lead to an improvement in employment and in turn in revenue and expenditure scenario since higher employment results in higher tax revenue and lower welfare expenditure. Also in the light of recent instances it is amply clear that there is an enormous political cost associated with forced government employment reduction and wage cut. It is widely believed today that given the enormity and complexity of the current problem, any sustainable fiscal consolidation will require a multi-pronged strategy.

To understand why a range of strategies should be employed in order to bring down public debt to sustainable levels, one can conceptually decompose public debt conceptually into three main structural components - primary balance, real growth differentials and interest payments ([Cottarelli et al. \[2010\]](#)). An increase in the growth rate of real GDP increases the revenue accrual to the government by increasing the tax receipt. This leads to a decrease in welfare expenditures too, thus having a direct bearing on the debt size. As servicing debt stock expend considerable part of the resources, interest rate movements have considerable impact on the debt size. However as [Cafiso \[2012\]](#) shows the largest component of debt-GDP ratio is mainly driven by the primary balance. He shows for EU-15¹ countries increase in primary balance accounts for 37 % of the share of debt-GDP ratio. This share is as high as 79 % in Spain, suggesting that any credible set of policies which intends to address public debt will directly need to tackle primary balance. This in turn will make a considerable impact on the two previous components through deficit-growth linkage and debt stock reduction.

The question then boils down to the following - What are the best ways of bringing down the primary balance. First, debt restructuring will have to play an important role inspite of repeated claims by the President of European Central Bank that public debt will not be written off under any circumstances. Especially, as noted by [Cabral \[2010\]](#), for Portugal, Ireland, Greece and Spain since Gross external debt position is very high which implies that interest payment for a majority of this debt is paid abroad and a tax on these interest payments accrue to governments abroad. So any attempt towards fiscal consolidation without incorporating debt restructure of some form or the other is likely to aggravate problem. Second, as has been widely noted in the literature it is important to reduce public expenditure which all these major debt ridden economies have started working on. But as is evident that this process of reducing public expenditure will be very painful not only in terms of employment but also in terms of

¹EU-15 countries include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom

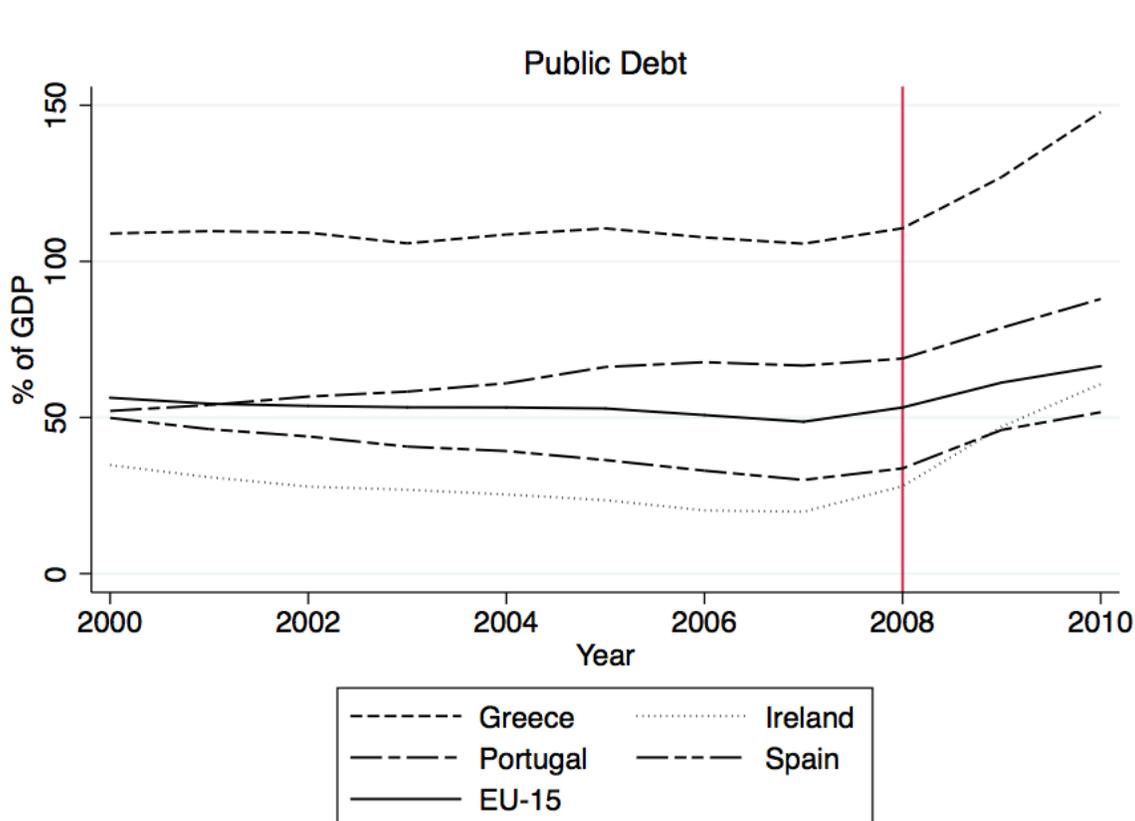
long term growth. Finally, the other option which has not been adequately explored is the possibility of raising tax revenue in these economies, through an increase in tax rate. Our objective in this paper is to explore in detail whether pursuing such a strategy makes sense in the current context.

3 Present Paradigm

The rise in debt-GDP ratio began from 2007 though its major escalation started in 2008. This was a global phenomenon. World leaders pledged collective action through fiscal stimulus to prevent the downward spiral of the world economy and high unemployment meant welfare expenditures were on the rise. Figure 1 shows how Greece and Portugal, whose debt-GDP ratio² was already at unsustainable levels, escalated by 40 percentage points and 20 percentage points respectively in the period 2008-10. Spain and Ireland suffered similar fate as a hitherto stable debt-GDP ratio saw a rapid rise - over 30 percentage points in the case of Ireland in the same period. The situation has come to such a passe today that for successful fiscal consolidation of EU, it is now believed that the required average total debt reduction per country will have to be to the tune of 37 percentage points of GDP.

²We use central government debt as reported by OECD Stat. as a measure of debt in this case

Figure 1: Central Government Debt as a Percentage of GDP

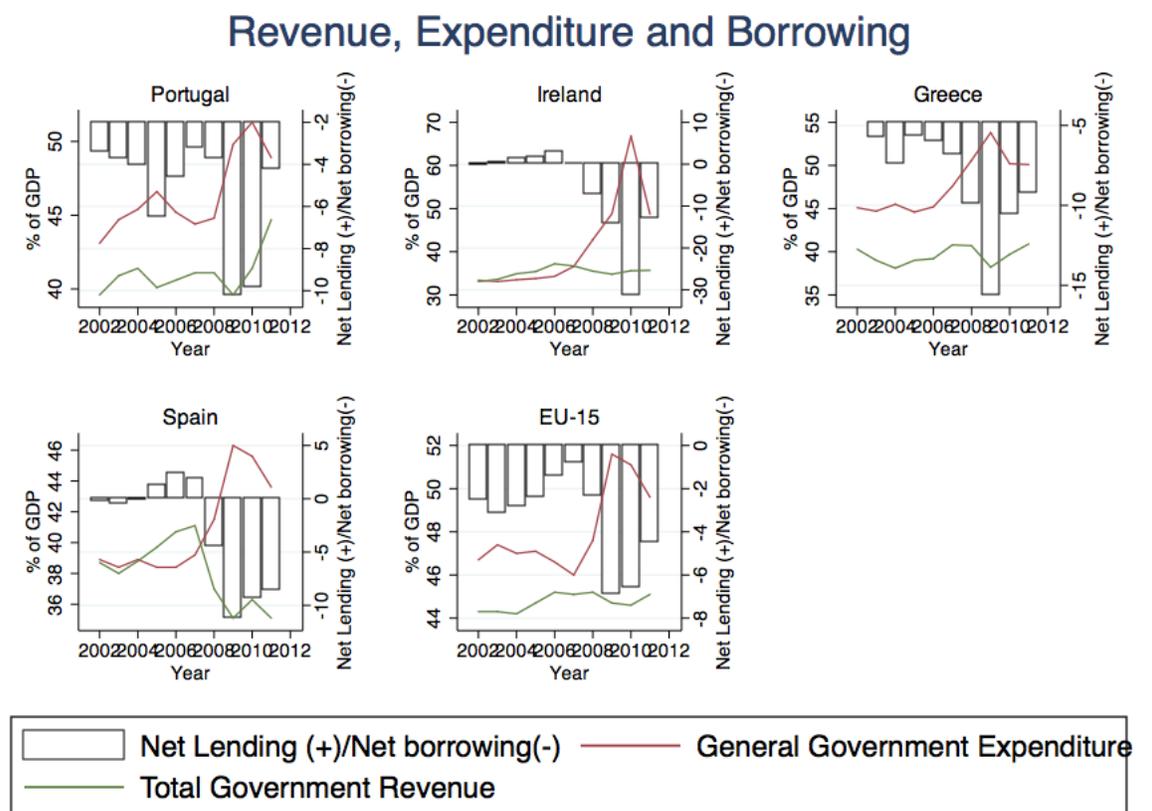


Source: OECD Stat.

The strategy of “growing out of debt” is clearly not feasible as the fundamentals of the economies are severely flawed. While Spain and Ireland have barely managed to maintain a positive growth in the last five quarters³ at 0.1% and 0.12% respectively, Portugal and Greece have been growing negatively at -0.6% and -1.48% respectively, during the same period. Thus they have taken recourse to improving the primary balance through painful spending cuts under the close monitoring of ECB, European Commission and the IMF, in order to allay market apprehensions of a possible bankruptcy. For example, the new Greek government has agreed to cut spending by 1.5% of GDP in order to obtain a substantial debt write-off. Other painful prescriptions for making structural changes like reducing the public sector employees by 150,000, pushing minimum wage from \$1000 a month to \$750 a month to enhance competitiveness of Greek workers etc. are under active consideration. The two year long austerity drive, coupled with a 19% unemployment and a deep recession is causing enormous social tensions in the country.

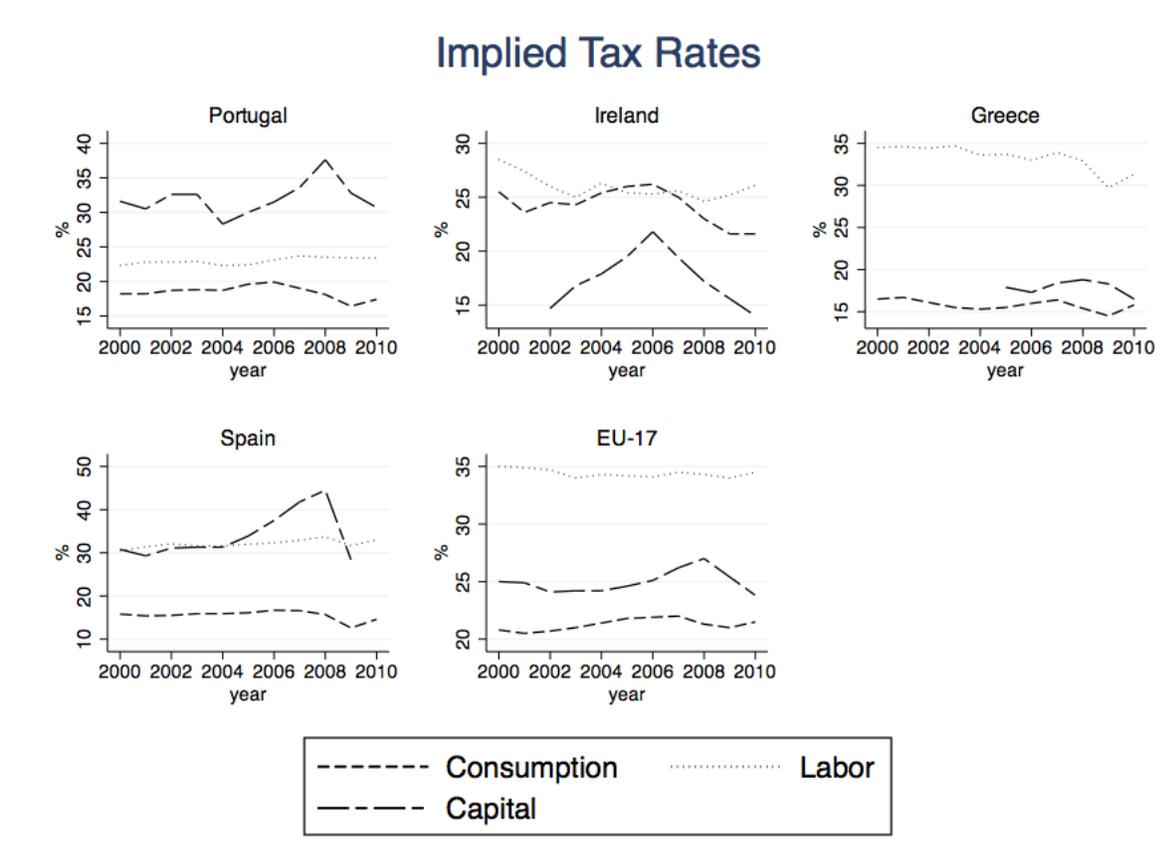
³Quarter 1, 2011 to Quarter 1, 2012. Source: IFS, IMF

Figure 2: Government Expenditure and Revenue



Our paper does not concern itself with investigating the reasons for such sharp increase in debt-GDP ratio, nonetheless a look at Figure 2 may be instructive. The government revenue had been falling for all of the above countries over the last decade. In the pre-crisis period, except Spain, all the countries have suffered tax revenue drop, which in the case of Greece has been rather consistent. The same graph however tells a different story so far as government expenditure is concerned which has been growing at steady rate throughout the decade. A closer look at the 2008-09 shows that while tax revenue fell in all countries, government expenditure continued to grow phenomenally. This was clearly the result of the expansionary stance taken by the governments and this in turn blew the lid off the debt-GDP ratio. Note that in a crisis year, a drop in tax-GDP ratio is not surprising but what we see is a consistent fall throughout the decade coupled with a decrease in the growth rate of tax revenue.

Figure 3: Tax Revenue as a % of GDP



Let us take a closer look the individual tax structures and see how in Euro region they stand vis a vis their taxation policies/system with data from Eurostat [2012] . A case by case overview from the above figure reveals that since the onset of crisis in 2008 (even prior to the crisis, as well) all of these four economies –Portugal, Ireland, Greece and Spain have lowest tax rates in the entire Euro region. Each of these countries has seen a secular decline in the capital tax rates. The tax on labor has declined in Greece and Ireland by as much as 5 pts over the decade. Not suprisingly Table 1 shows that Portugal is ranked 19th and Greece holds 21st rank in labour tax revenue, while Ireland is ranked 25th and Spain 27th in consumption tax revenue, in EU-27⁴. Considering each of these economies individually, shows that the overall tax revenue (including social security contribution) stood at 31.5% in Portugal, 28.2% in Ireland, 31% in Greece and 31.9% in Spain, much lower than EU-27 average which stood at 35.6% in 2010. While Portugal exhibits 8th lowest tax burden in EU-27, it currently has no wealth tax and in 2004 also abolished gift and inheritance taxes. In Ireland, tax system derives one of the smallest proportion of tax receipts from labour

⁴EU-14 comprises of Austria, Belgium, Denmark, Finland, France, Greece, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom. EU-15 comprises of EU-14 and Luxembourg. EU-27 comprises of EU-15 and Poland, Czech Republic, Cyprus, Latvia, Lithuania, Slovenia, Estonia, Slovakia, Hungary, Malta.

amounting to 41.4% much lower than EU-27 average of 47.3%. Further, in 2009, Ireland's total tax revenue to GDP reached the lowest value & remained at the same level in 2010, this was mainly driven by VAT, PIT & other taxes on products (incl. import duties) & corporate income taxes. Similar trend of lower tax rates is also observed in Greece, as the implicit tax rate on consumption stood at 15.8% much lower than EU-27 average of 21.3%, ranking second lowest in whole of Euro area. Even the ITR on capital declined from 18.8% in 2008 to 16.5% in 2010, well below the EU-27 average of 23.3%. In addition to this, there is no wealth tax, after 2010 reforms, the large properties are subject to recurrent tax levied at progressive rates ranging from 0.2% to 1%. Economy of Spain also confirms to this low level and trend of tax rates, as it exhibits the lowest level of consumption taxes which stands at 8.7% well below than 11.9% level of EU-27. Similarly implicit tax rates on capital experienced a large decline from a peak of 44.5% in 2007 to 28.4% in 2009 (values for 2010, NA). In addition to this post 2008 crisis, implicit tax rates on corporations collapsed severely from 63.3% in 2007 to 24.7% in 2009 but this was primarily driven by the fact that corporate profits punged.

Table 1: Tax Revenue as a percentage of GDP Structure by type of tax base

	Labor	Capital	Consumption
Portugal	12.9 (19)	6.9 (11)	11.7 (14)
Ireland	11.7 (23)	6.5 (14)	10.0 (25)
Greece	12.4 (21)	6.5 (13)	12.1 (11)
Spain	16.7 (14)	7.4 (10)	8.7 (27)

Source: Eurostat

Note: Figures in parenthesis represents ranking, which is calculated in descending order "1" indicates the highest value in EU-27

Furthermore besides having low tax rates, a glance at the borrowing levels of each of the economy from Figure 3 shows that their dovish fiscal policies coupled with high debt levels, resulted in extraordinary levels of borrowings in the last few years. Ireland and Spain used to be a net lender until 2006 and 2007 respectively until they started borrowing which was upto 30% of their GDP leading to a sudden jump in total interest payments.

This brings us to the question we are interested in. Does tax rate increase merit a relook so far as debt-reduction strategies are considered, especially given that tax rate in Europe has been monotonically falling through the decade? Even in these economies with rapidly rising public expenditure and falling tax-GDP ratio, tax rates have consistently decreased.⁵

⁵Our calculation shows that a simple measure of Average Personal Income Tax rate, obtained from an average of tax rate for Single parent without children, One-earner married couple with two children and two-earner married couple with two children, has steadily decreased. The decrease ranges from 1.4 percentage points in Greece to 1.7 percentage points in Ireland.

Laffer curve is one instrument through which we can locate an economy in a tax rate-tax revenue panel. We can assess whether the economy is on the left of the peak of the Laffer Curve, thus leaving us with a possibility of increase in tax revenue with a *ceteris paribus* increase in tax rate. Note that an increase in tax rate tends to adversely affect growth and thereby overall tax revenue. Thus we compute the dynamic steady state Laffer curves which reflect the locus of tax revenue after controlling for the loss in revenue due to the adverse impact growth. Though [Corsetti and Muller \[2012\]](#) conjecture that “there is equally little evidence to suggest that fiscal policy is on the wrong side of the Laffer curve”, dynamic laffer curves for debt ridden European economies have not been computed before. We solve a simple, closed dynamic model and compute this. Then we precisely locate four debt ridden economies, Greece, Portugal, Ireland and Spain in their corresponding dynamic Laffer Curves for different taxes and draw policy conclusions from there.

4 Model and Calibration

We solve a standard dynamic closed economy model to compute the steady state values of consumption, capital and labor supply. In our simple set up the consumers maximize their utility with respect to consumption and leisure, firms produce output using a Cobb Douglas technology and governments run a balanced budget⁶ where the tax revenue that it earns is used for lump sum transfer to the consumers and for providing with public goods which in turn enter the utility function of the consumers.

Formally the model can be written as follows -

$$\max_{c,l} \int_0^{\infty} \left(\ln c - \kappa l^{1+\frac{1}{\psi}} + \xi G^{1-n} \right) e^{-\rho t} dt$$

subject to $\dot{a} = (1 - \tau_w)wl + (1 - \tau_r)ra - (1 + \tau_c)c + T, a(0) = a_0$

where c, l, a are period consumption, leisure and assets; $\tau_c, \tau_r, \tau_w, T, w, r$ are consumption tax, capital tax, income tax, lump sum tax, wage and rental rate respectively; the constraint denotes the asset accumulation equation; the parameters ψ, ρ, κ and ξ denote the Frisch elasticity of labor supply, time preference rate, weight on disutility of labor and weight on government consumption. The model crucially rests on the assumption that government consumption G , enter the household utility separably from consumption and leisure⁷. Furthermore the preference

⁶In this case government running a balanced budget can be thought of as an infinite period present value budget balanced, though explicit characterization makes it difficult to solve. Also that brings in an additional element of debt dynamics. That may be a future work though where the debt position of each of these countries are compared against the steady state debt levels obtained through numerical solution of a dynamic model.

⁷[Christiano and Eichenbaum \[1992\]](#) was one of the first papers to use this preference. It can be interpreted as the entire government

has a constant Frisch elasticity of labor supply and the intertemporal elasticity of substitution is unity. Our utility function is a particular form of the general Constant Frisch Elasticity (CFE) utility function which appears in [Trabandt and Uhlig \[2010\]](#). It is this specification which yields unit intertemporal elasticity of substitution.

The standard first order conditions give us the Euler equation

$$\dot{c} = c((1 - \tau_p)r - \rho)$$

The firms maximize their profit and markets clear. We can then define the competitive equilibrium as the set of variables c, k, l, r, w which solve the following equations -

$$\begin{aligned} r &= \alpha k^{\alpha-1} l^{1-\alpha} - \delta \\ w &= (1 - \alpha) k^{\alpha} l^{-\alpha} \\ \dot{k} &= (1 - g) k^{\alpha} l^{1-\alpha} - c - \delta k \\ \dot{c} &= c((1 - \tau_p)r - \rho) \\ l^{\frac{1}{\psi}} &= \frac{w(1 - \tau_w)}{c(1 + \tau_c)(1 + \frac{1}{\psi})\kappa} \end{aligned}$$

I analytically derive the steady state values l_{ss}, k_{ss}, c_{ss} and numerically verify them. The steady state revenue calculation follows easily and is given by -

$$R_{ss} = \tau_w w l_{ss} + \tau_r r k_{ss} (1 - \delta) + \tau_c c_{ss}$$

A detailed solution of the model is given in the Appendix.

The model is calibrated to the data of the four economies we are interested in - Portugal, Ireland, Greece and Spain. European Union -14 has also been included in order that it serves as a reference point for the results we obtain from calibrating the individual economies. The calibrated values of consumption, labor and capital taxes are obtained from [Trabandt and Uhlig \[2010\]](#). Given the complexities involved in calibration of various country parameters, one litmus test for whether the parametrization can be thought of as reasonable, is if steady state solution for optimal labor hours worked is similar to prior studies. We use two values of the constant Frisch elasticity of labor supply with $\psi = 1$ and $\psi = 3$ in order to show robustness of our results⁸. Finally the steady state values are analytically

expenditure being used to produce public goods which in turn enter the preferences of the individuals.

⁸Our graphical analysis shows, $\psi = 3$ is close to the threshold choice of the Frisch elasticity parameter which makes revenue neutral with respect to tax increases. It is important to note however that [Trabandt and Uhlig \[2010\]](#) mentions $\psi = 1$ as their "preferred benchmark

computed and then numerically verified using the relaxation algorithm developed by [Trimborn et al. \[2008\]](#).

The relation algorithm is an efficient method of determining the transition process in growth models numerically. It can be used to compute a wide class of general equilibrium models. The transition process, which is a solution to a differential equation, is arrived at by using a trial solution which satisfies neither the slope condition nor the boundary conditions. Subsequently the corresponding error function is obtained and its first derivative is computed to improve the trial solution. At each point of iteration, the correction takes into account the deviation from the correct slope condition and also solves the static equation(s), until a predetermined threshold level of error is reached through a Newton type iteration.

Table 1 gives us the calibrated values of the tax rates of these economies in 2007 while Table 2 gives us the parameter values.

Table 2: Comparing Tax rates

	Labor Income Tax Rate	Capital Income Tax Rate	Consumption Tax rate
EU-14	41.3	34.4	16.9
Portugal	34.4	27.6	21.5
Ireland	28.5	22.5	25.6
Greece	40.3	14.5	21.5
Spain	37.4	36.2	14.7

Table 3: Parameter values

	α	δ	κ	G/y
EU-14	0.38	0.07	3.62	0.23
Portugal	0.39	0.10	3.39	0.23
Ireland	0.36	0.09	5.66	0.19
Greece	0.40	0.06	3.36	0.20
Spain	0.42	0.09	5.12	0.21

calibration".

5 Results

Table 4 gives us a first check about the consistency of the results obtained. It reports the the optimal labor choice predicted from the model and the corresponding value obtained from the data. The model predicted steady state solution for optimal labor hours for EU-14 is 0.24 with $\psi = 1$ and 0.23 with $\psi = 3$ while the data predicts it to be 0.20. It also confirms the well known fact that Greece with the level of labor tax that it has, exhibits one of the lowest preference for leisure, while for Ireland it is the highest.

Table 4: Comparing Tax rates

	EU-14	Greece	Ireland	Portugal	Spain
$\psi = 1$	0.24	0.28	0.23	0.31	0.24
$\psi = 3$	0.23	0.28	0.23	0.29	0.24
Data	0.20

Figure 4 gives us the Dynamic Laffer curve for consumption tax. The shape of the Laffer curve is dictated by the fact that consumption can never drop to zero. So in increasing the tax rate on the consumption has some rationale if the objective is solely how to generate surplus revenue, as the inelastic consumption will lead to an increase of tax revenue. The current consumption tax rate for each of the economies have been marked. A near constant slope implies a 10 percentage points (ppts henceforth) increase in consumption tax yields on an average a revenue increase of 15 per cent. A relatively steeper slope for Greece indicates that upto 20 per cent revenue increase can be achieved by a 10 ppts increase in consumption tax rate at the current tax levels.

Figure 5 shows the dynamic laffer curves for capital tax when the value of Frisch elasticity of labor supply is unity. Spain has the highest and Greece has the lowest capital tax rate among the four countries analyzed here . However irrespective of that it is evident from the graph that the possibility of enhancing the tax revenue by increasing the capital tax rate is limited. Infact the tax revenue sharply drops for any tax rate above 50 per cent. The average tax rate for EU-14 itself is quite high and does not merit any increase. A caveat must be in place though - the model that we calibrate does not incorporate the external sector. The result in the case of capital taxes may vary once that is incorporated as capital has a tendency to fly if adversely taxed. Having said that we note that [Trabandt and Uhlig \[2010\]](#) justify their assumption of closed economy by stating that if the model is viewed in the light of ownership based taxation instead of source based taxation then fiscal policy will not have much cross border effect.

Figure 6-10 gives us the dynamic laffer curves for income tax for each of the economies. Each panel computes the laffer curve for Frisch equals one and three. Greece has the highest income tax among them at over 40 per cent.

We find that while Spain and Portugal can only raise the tax revenue by 12 per cent and 12.5 per cent respectively by a 10 ppts increase in income tax rate at the current level of taxes. The corresponding figure for Greece and Ireland is 13 per cent and 14 per cent respectively. This suggests that there exists a possibility of a substantial increase in tax revenue through an increase in the income tax rate, particularly for Greece and Ireland. Even if such a tax increase were to take place, Irish economy will continue to be sufficiently to the left of the Laffer peak.

6 Conclusion

In many debt ridden countries the governments have tried to incorporate the painful process of fiscal discipline, though mostly unsuccessfully. In fact as we have seen in many cases a public debt reduction led by shedding government expenditure through employment and pay cut has resulted in enormous socio-political tensions. The consequence of a marginal increase in income tax rate on the other hand is much less. We solve a simple dynamic model and compute the dynamic Laffer curve for capital tax, income tax and consumption tax for four highly indebted economies - Portugal, Ireland, Greece and Spain. Our analysis shows under reasonable parametrization, there exists a scope for maneuverability with tax rates for consumption and labor tax. All the economies are located to the left of the Laffer peaks for the income tax and will be able to absorb marginal increase in tax rates with sacrificing growth rate. This has the potential to generate much needed resources to tackle the primary deficit in the short run which along with structural changes led expenditure cuts may be able bring down the debt to sustainable levels.

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Figure 4: Dynamic Laffer Curve for Consumption Tax

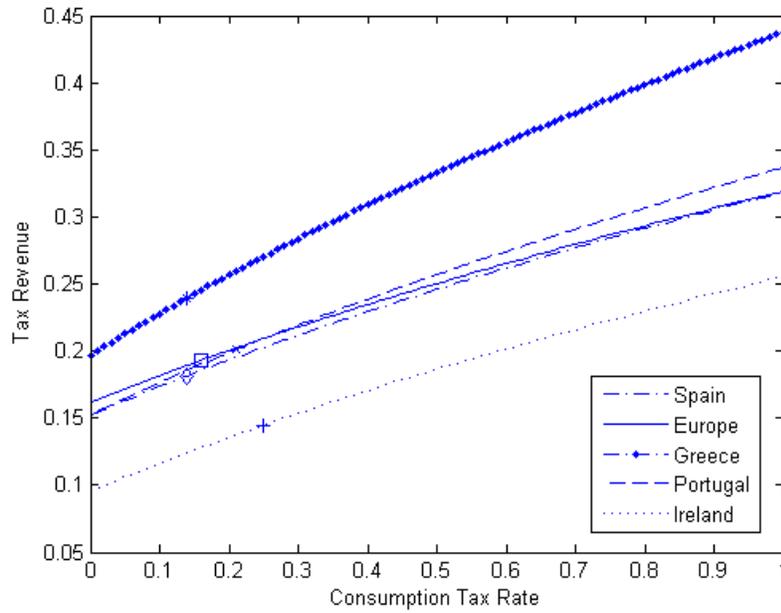
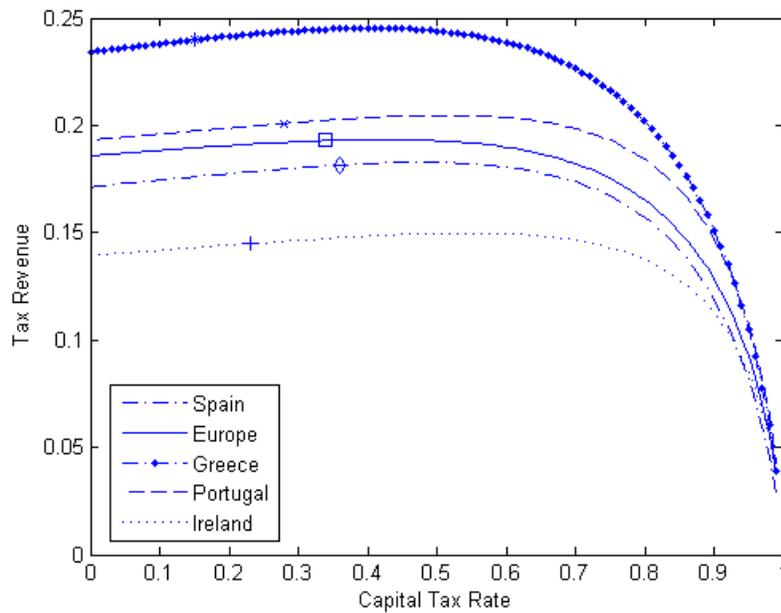


Figure 5: Dynamic Laffer Curve for Capital Tax



Note: Europe refers to EU-14

Figure 6: Dynamic Laffer Curve for Income Tax : EU-14

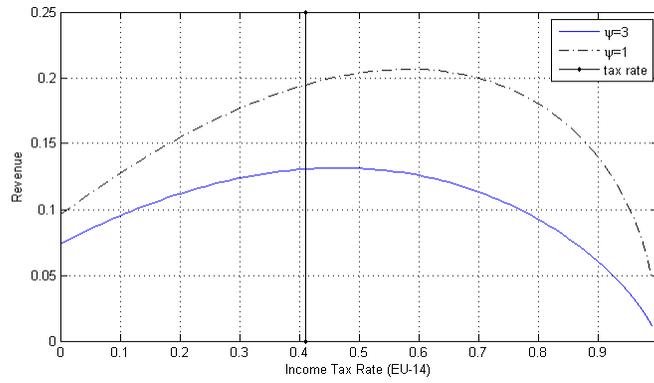


Figure 7: Dynamic Laffer Curve for Income Tax : Spain

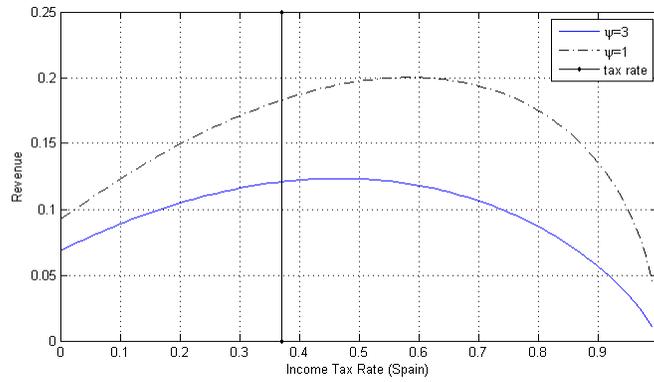


Figure 8: Dynamic Laffer Curve for Income Tax : Greece

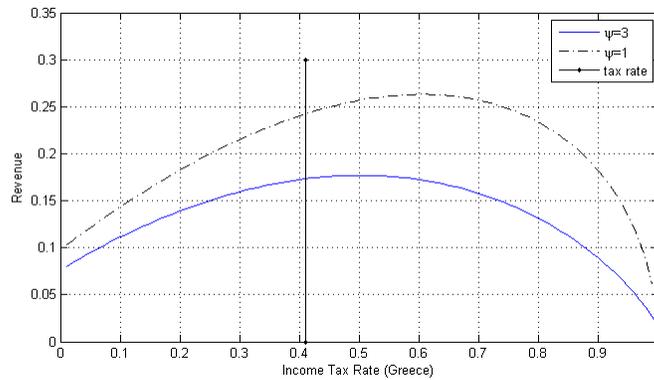


Figure 9: Dynamic Laffer Curve for Income Tax : Portugal

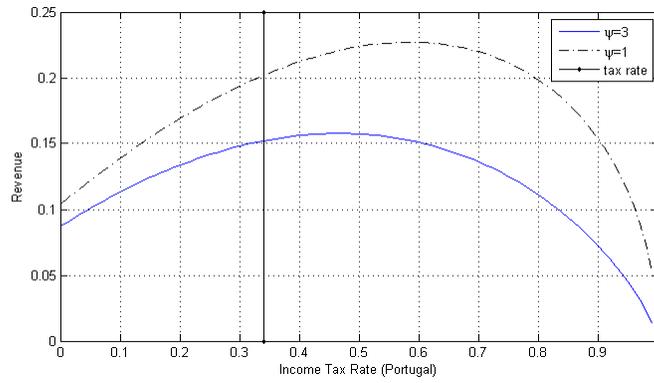
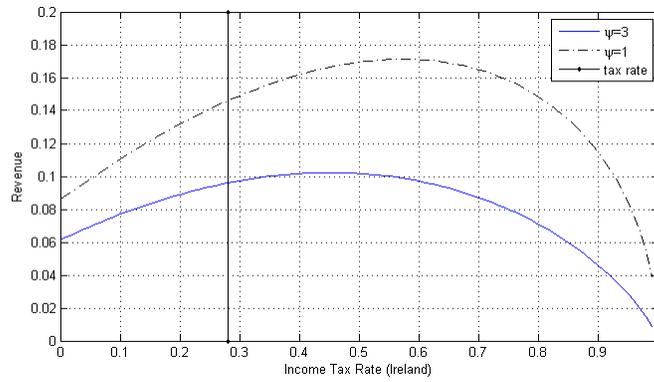


Figure 10: Dynamic Laffer Curve for Income Tax : Ireland



Appendix

A The Model

We model an infinite period, continuous time economy with households of unit measure, whose period utility depends on c_t , leisure $1 - l_t$ and consumption of goods provided by the government given by G_t . The household faces an asset accumulation equation and is subjected to different taxes (given in the equation). The optimization problem is

$$\max_{c,l} \int_0^{\infty} \left(\ln c - \kappa l^{1+\frac{1}{\psi}} + \xi G^{1-n} \right) e^{-\rho t} dt$$

$$\text{subject to} \quad \dot{a} = (1 - \tau_w)wl + (1 - \tau_r)ra - (1 + \tau_c)c + T, \quad a(0) = a_0$$

$$\text{where} \quad \tau_c \equiv \text{consumption tax}$$

$$\tau_r \equiv \text{capital tax}$$

$$\tau_w \equiv \text{income tax}$$

$$T \equiv \text{lumpsum tax}$$

$$w \equiv \text{wage}$$

$$r \equiv \text{rental rate}$$

The firms rent capital and labor and produce according to a Cobb-Douglas production function in a perfectly competitive factor markets

$$y = k^\alpha l^{1-\alpha}$$

Government run a balanced budget and the budget equation is given by

$$\tau_w wl + \tau_r ra + \tau_c c = T + G$$

The continuous time Bellman equation may be formulated as follows

$$\rho V(a) = \max e^{-\rho t} \left(\log(c) - \kappa l^{1+\frac{1}{\psi}} + \xi G^{1-n} \right) + \frac{d}{dt} V(a)$$

subject to asset accumulation equation

$$\dot{a} = (1 - \tau_w)wl + (1 - \tau_r)ra - (1 + \tau_c)c + T_t, \quad a(0) = a_0$$

The following are the first order conditions

$$\text{with respect to } c: \frac{1}{c} = V_a(1 + \tau_c) \quad (1)$$

$$\text{with respect to } l: \kappa \left(1 + \frac{1}{\psi}\right) l^{\frac{1}{\psi}} = V_a(1 - \tau_w)w$$

$$\implies l^{\frac{1}{\psi}} = \frac{w(1 - \tau_w)}{c(1 + \tau_c)\left(1 + \frac{1}{\psi}\right)\kappa} \quad (2)$$

$$\text{with respect to the state variable } a: \rho V_a = V_a(1 - \tau_p)r + \dot{a}V_{aa}$$

$$\implies V_a(\rho - (1 - \tau_p)r) = \dot{a}V_{aa} \quad (3)$$

Differentiating equation (1) with respect to t and then inserting in equation (3), we obtain the Euler equation is given by

$$\dot{c} = c((1 - \tau_p)r - \rho)$$

In a freely competitive market the wages and rentals for capital may be calculated from the profit maximizing conditions of the firm.

$$r + \delta = \alpha k^{\alpha-1} l^{1-\alpha} \quad (4)$$

$$\text{and } w = (1 - \alpha)k^{\alpha} l^{-\alpha} \quad (5)$$

Accounting identity would necessitate the following condition

$$\begin{aligned} Y &= c + \dot{k} + \delta k + G \\ \dot{k} &= (1 - g)y - c - \delta k \end{aligned} \quad (6)$$

We get equation (6) from the assumption that $G = gY$.

Thus we have a complete characterization of the model given the capital market clears. The competitive equilibrium of the economy is given by the set of variables c, k, l, r, w which satisfy the following equations

$$\begin{aligned} r &= \alpha k^{\alpha-1} l^{1-\alpha} - \delta \\ w &= (1 - \alpha) k^{\alpha} l^{-\alpha} \\ \dot{k} &= (1 - g) k^{\alpha} l^{1-\alpha} - c - \delta k \\ \dot{c} &= c((1 - \tau_p)r - \rho) \\ l^{\frac{1}{\psi}} &= \frac{w(1 - \tau_w)}{c(1 + \tau_c)(1 + \frac{1}{\psi})\kappa} \end{aligned}$$

The steady state characterization of the economy is given by

$$\begin{aligned} l_{ss} &= \left(\frac{(\rho + (1 - \tau_p)\delta)(1 - \alpha)(1 - \tau_w)}{(1 + \tau_c)(1 + \frac{1}{\psi})\kappa[(1 - g)(\rho + (1 - \tau_p)\delta) - \delta\alpha(1 - \tau_p)]} \right)^{\frac{\psi}{1+\psi}} \\ k_{ss} &= \left[\frac{1}{\alpha} \left(\frac{\rho}{(1 - \tau_p)} + \delta \right) \right]^{\frac{1}{1-\alpha}} \left(\frac{(\rho + (1 - \tau_p)\delta)(1 - \alpha)(1 - \tau_w)}{(1 + \tau_c)(1 + \frac{1}{\psi})\kappa[(1 - g)(\rho + (1 - \tau_p)\delta) - \delta\alpha(1 - \tau_p)]} \right)^{\frac{\psi}{1+\psi}} \\ c_{ss} &= \left[(1 - g) \frac{1}{\alpha} \left(\frac{\rho}{(1 - \tau_p)} + \delta \right) - \delta \right] \left[\frac{1}{\alpha} \left(\frac{\rho}{(1 - \tau_p)} + \delta \right) \right]^{\frac{1}{1-\alpha}} \left(\frac{(\rho + (1 - \tau_p)\delta)(1 - \alpha)(1 - \tau_w)}{(1 + \tau_c)(1 + \frac{1}{\psi})\kappa[(1 - g)(\rho + (1 - \tau_p)\delta) - \delta\alpha(1 - \tau_p)]} \right)^{\frac{\psi}{1+\psi}} \end{aligned}$$

The total revenue for the government is given by

$$R_{ss} = \tau_w w l_{ss} + \tau_r r k_{ss} + \tau_c c_{ss}$$