Optimal Tax Rates and Laffer Curve Analysis for India

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Contents

Outline

Outline of the Presentation

In this study, we

- Construct a closed-economy, neoclassical growth model, building upon Trabandt and Uhlig (2011)
- Introduce **heterogeneous agents** and **tax evasion** into the model
- Derive the Laffer curve and estimate optimal tax rates for the Indian economy along the balanced growth path, i.e., tax rates that maximise tax revenues
- Assess how the optimal tax rates change with a change in institutional factors that affect tax compliance

Contribution

- Conducting a theoretical analysis on optimal tax rates for India
- Adding features specific to the Indian economy: tax evasion, tax exemptions (heterogeneous agents), administrative quality
- Incorporating culture of tax evasion through a 'shame' parameter (work in progress)

Introduction

Laffer Curve

A simple inverse U-shaped curve that is a matter of complex debate[3] [4] *and the main tool of our study.*

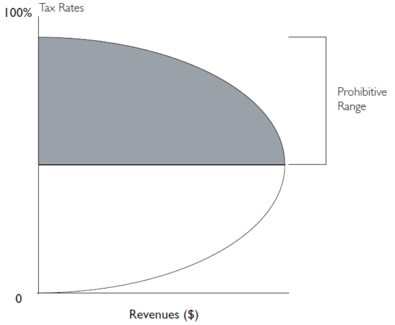


Figure 1: Laffer Curve (Source: Laffer (2004))

[3] *The Rise and Fall of Laffer Curve*

[4] *Is the Laffer Curve Political?*

But why Laffer Curve?

- Simple framework to deal with complex issues
- Implicitly incorporates the notions of tax effort v/s tax capacity
- Lends itself to real-life application

The India Story

"The tax revenue in the Union Budget for 2021-22 was estimated at Rs. 22.17 lakh crore against the revised estimates of Rs. 19 lakh crore... This revenue growth has been propelled by rapid economic recovery after successive waves of COVID... **supplemented with better compliance efforts in taxation... through use of technology and artificial intelligence**"[5]

[5] *Ministry of Finance Press Release, 8th April 2022*

Tax to GDP Ratio

- Tax to GDP ratio is lower for emerging economies than for advanced economies
- Increased marginally by around 1.2 per cent for India between 2012 and 2018

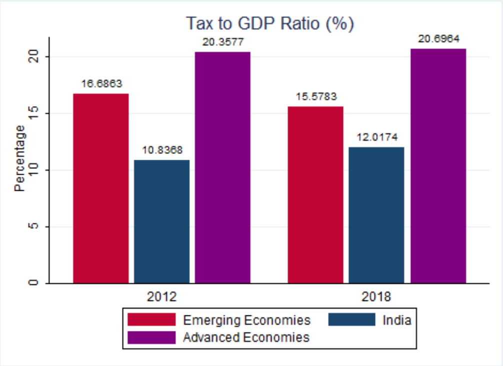


Figure 2: Tax to GDP Ratio

Appendix

Control of Corruption

- Control of Corruption Indicator (World Development Indicators) lies between -2.5 and +2.5 (lower value indicates use of public power for private gain)
- Countries with higher per capital GDP fare better on control of corruption

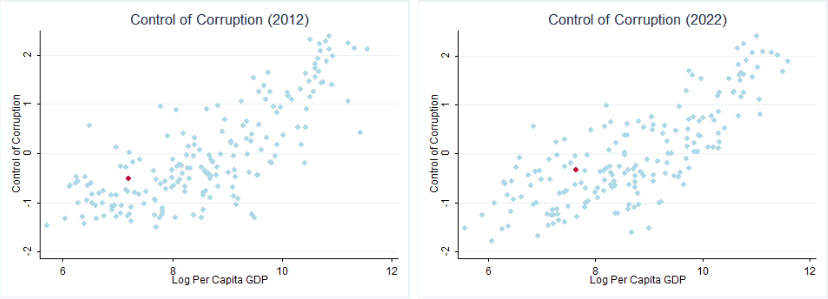


Figure 3: Control of Corruption ▸ Appendix

Control of Corruption

- Advanced economies have a higher Control of Corruption Index than emerging economies
- Value for India at -0.51 in 2012, improved to -0.32 by 2022

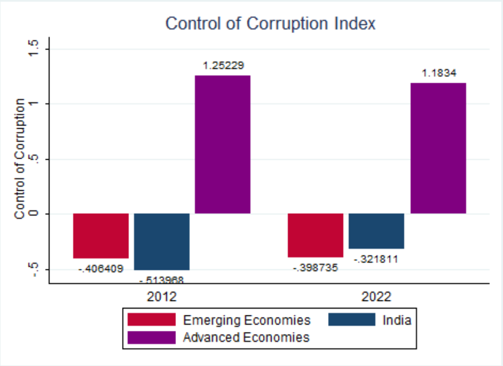


Figure 4: Control of Corruption

Government Effectiveness

- Government Effectiveness Indicator (World Development Indicators) lies between -2.5 and +2.5 (indicates quality of public services, policy implementation)
- Countries with higher per capital GDP fare better on government effectiveness

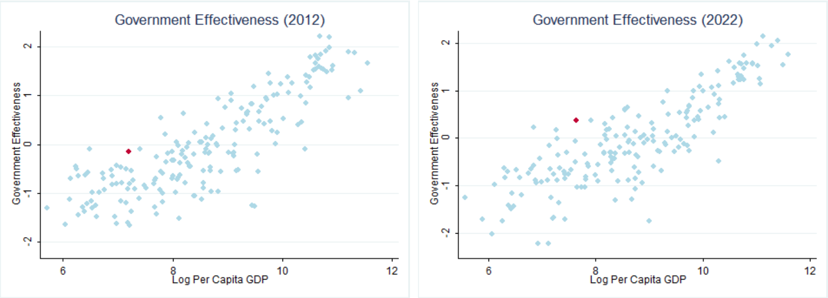


Figure 5: Government Effectiveness ▸ Appendix

Government Effectiveness

- Advanced economies have a higher Government Effectiveness Index than emerging economies
- Value for India at -0.15 in 2012, improved to 0.37 by 2022

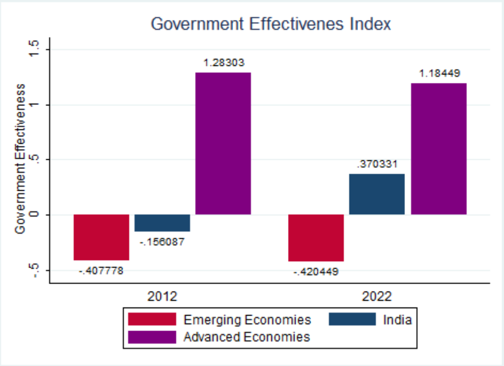


Figure 6: Government Effectiveness

Hours Required by Firms to File Taxes in a Year

- Indicates the level of complexity and bureaucratic delays involved in the tax administration of the country (Doing Business Survey)
- Much lower for advanced economies than for emerging economies
- Reduced marginally between 2014 and 2020

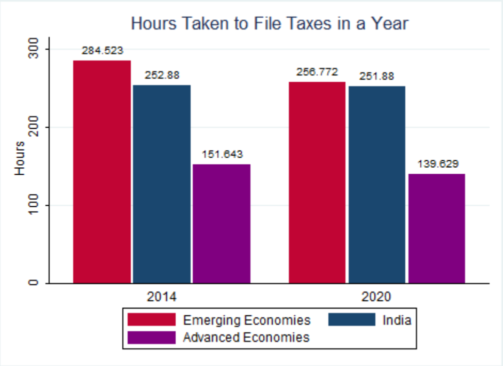


Figure 7: Hours to File Taxes ▸ Appendix

Income Tax Slabs

- Trabandt and Uhlig (2011) conduct the Laffer curve analysis for the US and EU-14
- The US, as well as countries part of the EU-14 such as Belgium, Denmark and Finland do not have tax exemptions for the low-income earners
- On the other hand, India has tax exemptions for the low-income earners (individuals earning less than Rs. 3,00,000 annually)
- We aim to capture this distinction in a heterogeneous agents set-up

Literature Review

Strands of Literature

1. Fiscal Policy: Optimal Taxation
2. Tax Evasion
3. Institutional Quality

Fiscal Policy: Optimal Taxation

- Trabandt and Uhlig (2011) construct a neoclassical growth model and generate Laffer curves for US and EU-14
- Alba and McKnight (2022) introduce informal sector into the above model and generate Laffer curves for Latin American countries
- Nutahara (2015) conducts a similar exercise for Japan
- Dearth of such theoretical analyses in the Indian context

Tax Evasion

- Busato and Chiarini (2013) add the underground economy, and find that the Laffer curve with the underground economy (proxy for tax evasion) is at all points below that for the economy without tax evasion
- Underground economy/informal sector used as proxy for tax evasion; however tax evasion can occur in the formal sector as well
- In our model, $1 - \gamma$ is the proportion of tax evaders, which we aim to endogenise

Institutional Quality

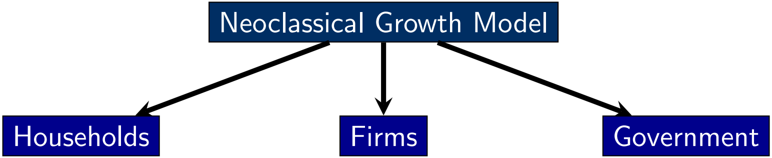
- Papp and Takáts (2008) construct a general equilibrium model with tax evasion, tax audits and a 'shame' parameter that captures the 'culture of corruption' effect
- Jayawardane (2015) talks about the impact of social norms in affecting tax compliance
- Jha et al. (1999) observe that tax efficiency of Indian states depends on factors such as administrative efforts, rationalisation of tax structure and efforts to minimise tax avoidance and evasion
- We introduce the impact of institutional factors such as tax audit efforts and culture of corruption on optimal tax rates

Model

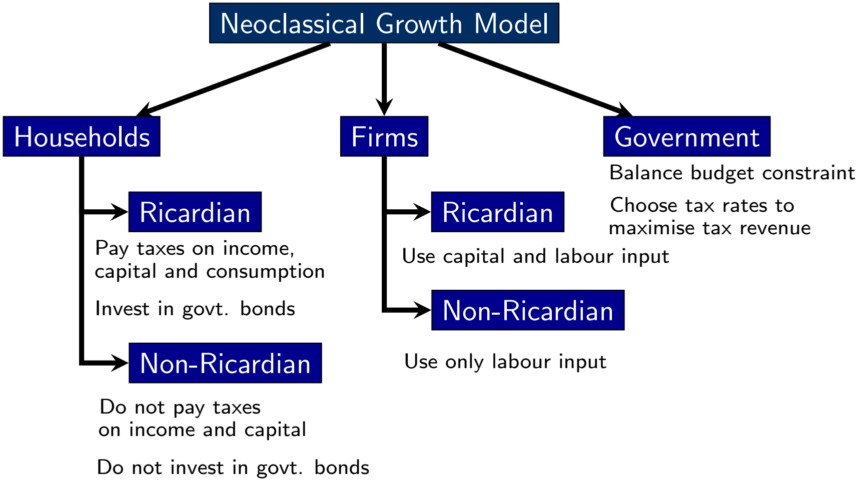
Outline of the Model

Neoclassical Growth Model

Outline of the Model



Outline of the Model



Salient Features

- Presence of Ricardian and non-Ricardian households, with share $1-\omega$ and ω respectively
- Taxes on capital and labour can be evaded, with $1-\gamma$ being the proportion of tax evaders, while taxes on consumption cannot be evaded
- For the tax evaders, μ is the probability with which they get caught
- If a tax evader gets caught, they pay a penalty at the rate $\pi\nu$, with π being the monetary penalty and a shame parameter ν

Households

- Two types: Ricardian and non-Ricardian
- Ricardian households pay tax on labour, capital and consumption; they save and invest
- Non-Ricardian households exempt from labour and capital tax; do not save or invest
- ω is the proportion of non-Ricardian households

Ricardian Households

- Choose consumption c_t^r, labour supply n_t^r, investment x_t and government bond holdings b_t to maximise utility $U(c_t^r, n_t^r)$, subject to household budget constraint and capital accumulation equation
- Expenditures consist of consumption c_t^r, investment x_t and purchases of government bonds b_t
- Income consists of labour income $w_t^r n_t^r$, capital income $d_t k_{t-1}$, interest on government bonds $R_t^b b_{t-1}$, lump-sum transfers from government s_t and firm profits Π_t^r

Ricardian Households

- Consumption is taxed at rate τ_t^c, wage income is taxed at rate τ_t^n and capital income net of depreciation δ is taxed at rate τ_t^k
- γ proportion of households pay taxes honestly and $1 - \gamma$ proportion of households evade taxes
- For the tax evaders, μ is the probability that they will be caught
- If caught in tax evasion, households pay a penalty at the rate $\pi\nu$, consisting of monetary penalty π and 'shame' parameter ν

Ricardian Households

The representative Ricardian household has the following budget constraint:-

$$
\begin{aligned}
(1+\tau_t^c)c_t^r + x_t + b_t = & [1-\tau_t^n(\gamma+(1-\gamma)\mu(1+\pi\nu)]w_t^r n_t^r \\
& + [1-\tau_t^k(\gamma+(1-\gamma)\mu(1+\pi\nu)](d_t-\delta)k_{t-1} \\
& + \delta k_{t-1} + R_t^b b_{t-1} + s_t + \Pi_t^r
\end{aligned} \tag{1}
$$

and capital accumulation equation:-

$$
k_t = (1-\delta)k_{t-1} + x_t \tag{2}
$$

The Ricardian households maximise their discounted sum of utility:-

$$
\max_{c_t^r, n_t^r, k_t, b_t} E_0 \sum_{t=0}^{\infty} \beta^t [u(c_t^r, n_t^r) + \vartheta(g_t)]
$$

subject to (1) and (2), taking government expenditure g_t as given

Ricardian Households

The first-order conditions are as follows:-

$$\lambda_t = \frac{u'_{c^r}}{(1+\tau_t^c)} \tag{3}$$

$$\lambda_t = \frac{-u'_{n^r}}{\{1-\tau_t^n[\gamma+(1-\gamma)\mu(1+\pi\nu)]\}w_t^r} \tag{4}$$

$$\lambda_t = \beta\lambda_{t+1}[1+(1-\gamma)(1-\mu\tau_{t+1}^k(1+\pi\nu))(d_{t+1}-\delta)+\gamma(1-\tau_{t+1}^k)(d_{t+1}-\delta)] \tag{5}$$

$$R_{t,t+1}^b = \frac{\lambda_t}{\beta\lambda_{t+1}} \tag{6}$$

Combining the above two equations, we have:-

$$R_{t,t+1}^b = 1+(1-\gamma)(1-\mu\tau_{t+1}^k(1+\pi\nu))(d_{t+1}-\delta)+\gamma(1-\tau_{t+1}^k)(d_{t+1}-\delta) \tag{7}$$

where λ_t is the Lagrangean multiplier. ▸ Appendix

Non-Ricardian Households

- Choose consumption $c^{nr}_{nr,t}$ and labour supply n^{nr}_t to maximise utility $U(c^{nr}_{nr,t}, n^{nr}_t)$, subject to household budget constraint
- Expenditures consist of consumption c^{nr}_t (only on Type R goods)
- Income consists of labour income $w^{nr}_t n^{nr}_t$, lump-sum transfers from government s_t and firm profits Π^{nr}_t
- Consumption is taxed at rate τ^c_t; labour income is exempt from taxation

Non-Ricardian Households

The representative non-Ricardian household has the following budget constraint:-

$$(1+\tau_t^c)T_t^{nr}c_t^{nr} = T_t^{nr}w_t^{nr}n_t^{nr} + s_t + \Pi_t^{nr} \tag{8}$$

The non-Ricardian households maximise their discounted sum of utility:-

$$\max_{c_{nr,t}^{nr},\, n_t^{nr}} E_0 \sum_{t=0}^{\infty} \beta^t [u(c_{nr,t}^{nr}, n_t^{nr}) + \vartheta(g_t)]$$

subject to 8, taking government expenditure g_t as given

The first-order conditions are given as follows:-

$$\tilde{\lambda}_t = \frac{u'_{c^{nr}}}{(1+\tau_t^c)T_t^{nr}} \tag{9}$$

$$\tilde{\lambda}_t = \frac{-u'_{n^{nr}}}{w_t^{nr}T_t^{nr}} \tag{10}$$

where $\tilde{\lambda}_t$ is the Lagrangean multiplier ▸ Appendix

Aggregates

The aggregate budget constraint for the economy is given as follows:-

$$C_t + (1-\omega)x_t + g_t = Y_t$$

where:-

$C_t = (1-\omega)c_t^r + \omega T_t^{nr} c_{nr,t}^{nr}$
$Y_t = (1-\omega)y_t^r + \omega T_t^{nr} y_{nr,t}^{nr}$
$c_t^r = T_t^r c_{r,t}^r + T_t^{nr} c_{nr,t}^r$
$c_t^{nr} = T_t^{nr} c_{nr,t}^{nr}$

Appendix

Firms

- Two types of firms: Type R (owned by Ricardian households) and Type NR (owned by non- Ricardian households)
- Type R firms produce final output y_t^r using labour and capital input, i.e., n_t^r and k_t
- Type NR firms produce output y_t^{nr} using only labour input n_t^{nr}
- Firms operate under perfect competition
- Total factor productivity grows at the rate A^r for Type R firms, which is higher than A^{nr} for Type NR firms
- $\zeta^r = (A^r)^{\frac{1}{1-\theta}}$ (technological progress is labour-augmenting, Uzawa (1961)) and $\zeta^{nr} = (A^{nr})$ are growth factors of aggregate output for Type R and Type NR firms resp.

Type R Firms

Type R firms operate using the Cobb-Douglas production technology as follows:-

$$y_t^r = (A^r)^t k_{t-1}^{\theta} (n_t^r)^{1-\theta} \tag{11}$$

Firms choose capital and labour inputs to maximise profits $\Pi_t^r = y_t^r - w_t^r n_t^r - d_t k_{t-1}$ subject to (11), where w_t^r and d_t refer to return to labour (wage rate) and return to capital respectively

The first order conditions for the above problem are given as follows:-

$$d_t = \theta \frac{y_t^r}{k_{t-1}} \tag{12}$$

$$w_t^r = (1-\theta) \frac{y_t^r}{n_t^r} \tag{13}$$

Type NR Firms

Type NR firms operate using the following production technology:-

$$y_t^{nr} = (A^{nr})^t n_t^{nr} \tag{14}$$

Firms choose labour input to maximise profits $\Pi_t^{nr} = y_t^{nr} - w_t^{nr} n_t^{nr}$ subject to (14), where w_t^{nr} refers to return to labour (wage rate)

The first order condition for the above problem is given as follows:-

$$w_t^{nr} = \frac{y_t^{nr}}{n_t^{nr}} \tag{15}$$

Government

- Maintains balanced budget
- Spends on consumption g_t
- Issues bonds b_t and pays interest on bonds R_t^b
- Provides lump-sum transfers s_t to households
- Collects tax revenues T_t; chooses tax rates on labour income τ_t^n, capital income τ_t^k and consumption τ_t^c to maximise tax revenues

Government

The government budget constraint is given by

$$g_t + s_t + R_t^b b_{t-1} = b_t + T_t \tag{16}$$

where tax revenues are the sum of tax on consumption, labour income and capital income:-

$$\begin{aligned} T_t =& \tau_t^c[\omega c_t^{nr} + (1-\omega)c_t^r] + \\ & (1-\omega)[\gamma + (1-\gamma)\mu(1+\pi\nu)][\tau_t^n w_t^r n_t^r + \tau_t^k (d_t - \delta)k_{t-1}] \end{aligned} \tag{17}$$

where
$c_t^r = T_t^r c_{r,t}^r + T_t^{nr} c_{nr,t}^r$
$c_t^{nr} = T_t^{nr} c_{nr,t}^{nr}$

Balanced Growth Path

Capital to Output Ratio

$$\overline{k/y^r} = [\frac{\overline{R^b} - 1}{\theta[1 - \overline{\tau^k}(\gamma + (1-\gamma)\mu(1+\pi\nu))]} + \frac{\delta}{\theta}]^{-1} \tag{18}$$

- Independent of tax on labour and consumption
- Decreases in tax on capital
- Falls as returns on bonds rise

Appendix

Balanced Growth Path

Consumption to Output Ratio (Ricardian)

$$\overline{\alpha^r}(\overline{c^r/y^r}) = 1 - \frac{1}{\eta} + (\eta\kappa^r(\overline{n}^r)^{1+\frac{1}{\psi}})^{-1} \tag{19}$$

where $\overline{\alpha^r} = \frac{(1+\overline{\tau^c})(1+\frac{1}{\psi})}{[1-\overline{\tau^n}(\gamma+(1-\gamma)\mu(1+\pi\nu))](1-\theta)}$

- Falls with a rise in tax on consumption and tax on labour income
- Increases with a rise in share of labour in output $1-\theta$ and intertemporal elasticity of substitution η
- Falls with rise in Frisch elasticity of labour supply ψ

Consumption to Output Ratio (Non-Ricardian)

$$\overline{\alpha^{nr}}(\overline{c^{nr}/y^{nr}}) = 1 - \frac{1}{\eta} + (\eta\kappa^{nr}(\overline{n}^{nr})^{1+\frac{1}{\psi}})^{-1} \tag{20}$$

where $\overline{\alpha^{nr}} = (1+\overline{\tau^c})(1+\frac{1}{\psi})$ Appendix

Balanced Growth Path

Labour Choice (Ricardian)

$$\overline{\alpha^r}(\chi + \gamma\frac{1}{\overline{n^r}}) = 1 - \frac{1}{\eta} + (\eta\kappa^r(\overline{n}^r)^{1+\frac{1}{\psi}})^{-1} \tag{21}$$

where

$\chi =$

$\frac{1}{(1+\overline{\tau^c})}\{1-(\zeta^r-1+\delta)\overline{k/y^r}-[\gamma+(1-\gamma)\mu(1+\pi\nu)][\overline{\tau^n w^r}\frac{(\overline{k/y^r})^{\frac{-\theta}{1-\theta}}}{\zeta^r}+\overline{\tau}^k(\overline{d}-\delta)\overline{k/y^r}]\}$

$\gamma = \frac{1}{(1+\overline{\tau^c})}\frac{(\overline{k/y^r})^{\frac{-\theta}{1-\theta}}}{\zeta^r}[\overline{b}(\overline{R^b} - \zeta^r) + \overline{s}]$

Labour Choice (Non-Ricardian)

$$\overline{\alpha^{nr}}\frac{1}{(1+\overline{\tau^c})}[1 + \overline{s}/\overline{(y^{nr}T^{nr})}] = 1 - \frac{1}{\eta} + (\eta\kappa^{nr}(\overline{n}^{nr})^{1+\frac{1}{\psi}})^{-1} \tag{22}$$

Appendix

Balanced Growth Path: Laffer Curve

The expression for the Laffer curve along the balanced growth path is given as follows:-

$$
\begin{aligned}
L = & \overline{\tau^c}(\omega\overline{(c^{nr}/y^{nr})}\,\overline{y^{nr}}/\overline{y^r} + (1-\omega)\overline{(c^r/y^r)}) \\
& + (1-\omega)[\gamma + (1-\gamma)\mu(1+\pi\nu)][\overline{\tau^n}(1-\theta) + \overline{\tau^k}(\theta - \delta\overline{k/y^r})]
\end{aligned} \quad (23)
$$

▸ Appendix

Data and Calibrations

Data Collection and Calibration

- Data for initial calibration has been collected fron CEIC and RBI Handbook of Statistics
- Data on tax rates is from the Trading Economics website
- We have used data for the time period 2012-2022
- Matlab version R2021a used to obtain the results

Summary Statistics

Variable	India
$\overline{k/y}$	3.086
$\overline{b/y}$	0.040
$\overline{x/y}$	0.229
$\overline{c/y}$	0.589
$\overline{g/y}$	0.108
$\overline{n}$	0.399
$\overline{\tau^k}$	0.313
$\overline{\tau^n}$	0.365
$\overline{\tau^c}$	0.158
$\overline{T_k/y}$	0.032
$\overline{T_n/y}$	0.023
$\overline{T_c/y}$	0.050

Table 1: Average (2012-2022): Calculated by Authors

Calibrated Values

Calibrations		
Parameter	**Benchmark Case**	**Source**
$\overline{R}$	1.04	Trabandt and Uhlig (2011)
η	1	Trabandt and Uhlig (2011)
ψ	0.5	Trabandt and Uhlig (2011)
A^r	1.02	Trabandt and Uhlig (2011)
A^{nr}	1.001	Assumption
θ	0.38	Trabandt and Uhlig (2011)
δ	0.07	Trabandt and Uhlig (2011)
μ	0.5	Assumption
γ	0.6	Dholakia (2022)
π	3	Papp and Takáts (2008)
ν	1	Papp and Takáts (2008)
ω	0.75	Assumption

Table 2: Calibrations

Results

Benchmark Case

- Optimal tax rates are at 33 per cent for capital, 54 per cent for labour and 99 per cent for consumption
- Optimal tax rate on labour is higher than average statutory tax rate for 2012-2022
- Tax revenue at average tax rate (black vertical line) normalised to 100

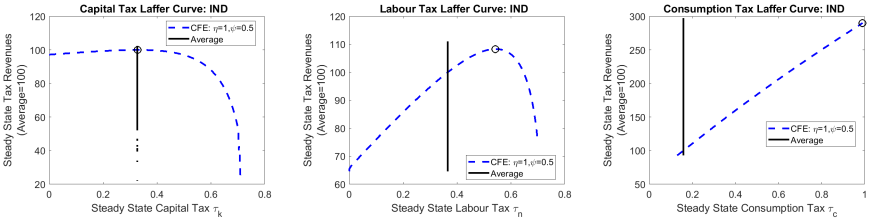


Figure 8: Results from Benchmark Calibration

Sensitivity: Share of non-Ricardian Sector

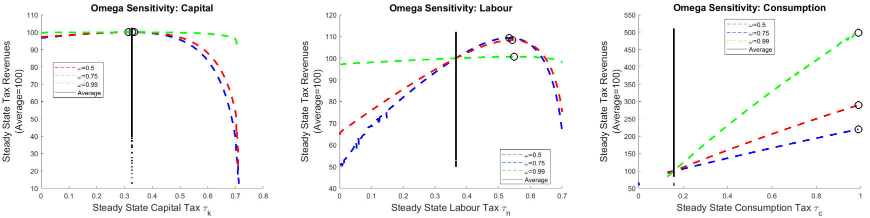


Figure 9: Sensitivity Analysis: ω

ω	τ_k	Maximum Tax Revenues	τ_n	Maximum Tax Revenues	τ_c	Maximum Tax Revenues
0.5	0.32	100.01	0.53	109.38	0.99	220
0.75	0.33	100	0.54	108.32	0.99	289.99
0.99	0.34	100	0.55	100.71	0.99	498.44

Table 3: Sensitivity Analysis: ω

Takeaways

- Tax base for labour and capital tax falls
- Maximum tax revenues generated from tax on labour fall by around 9 per cent
- Non-Ricardian households consume more (no investment, no bond-holdings)
- Maximum tax revenues generated from tax on consumption rise by more than 100 per cent
- Tax rates do not shift much

Sensitivity: Proportion of Honest Taxpayers

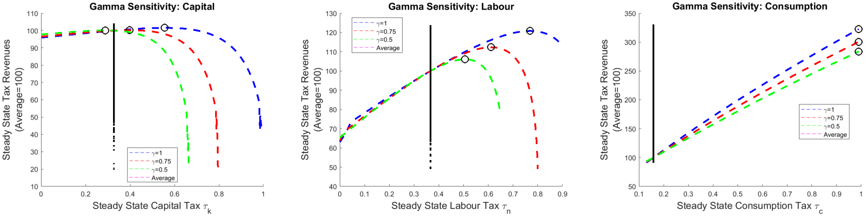


Figure 10: Sensitivity Analysis: γ

γ	τ_k	Maximum Tax Revenues	τ_n	Maximum Tax Revenues	τ_c	Maximum Tax Revenues
1	0.56	101.61	0.77	120.81	0.99	322.58
0.75	0.4	100.23	0.61	112.33	0.99	300.66
0.5	0.29	100.09	0.51	106.06	0.99	283.84

Table 4: Sensitivity Analysis: γ

Takeaways

- As tax evasion rises, tax base and tax capacity fall
- Optimal tax rate on capital falls from 56 per cent to 29 per cent
- Optimal tax rate on labour falls from 77 per cent to 51 per cent
- Reduced elasticity for government to set high tax rates

Sensitivity: Probability of Getting Caught

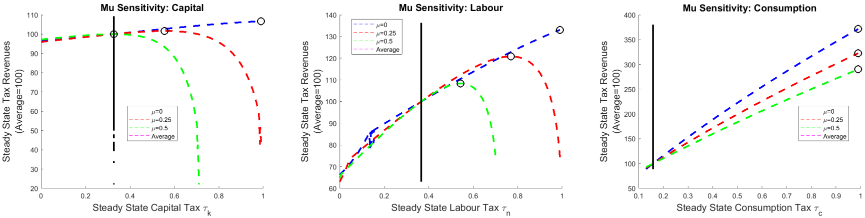


Figure 11: Sensitivity Analysis: μ

μ	τ_k	Maximum Tax Revenues	τ_n	Maximum Tax Revenues	τ_c	Maximum Tax Revenues
0	0.99	106.62	0.99	133.03	0.99	371.38
0.25	0.56	101.61	0.77	120.81	0.99	322.58
0.5	0.33	100	0.54	108.32	0.99	289.99

Table 5: Sensitivity Analysis: μ

Takeaways

- Tax rates set to highest possible rate when probability of catching evaders is zero
- Tax rate will also affect degree of tax evasion (work in progress)
- Optimal tax rates required to generate revenues fall as it becomes easier to catch tax evaders
- Tax revenues on capital and labour tax fall by around 6 per cent and 25 per cent respectively, as economic activity disincentivised

Sensitivity: Penalty on Getting Caught

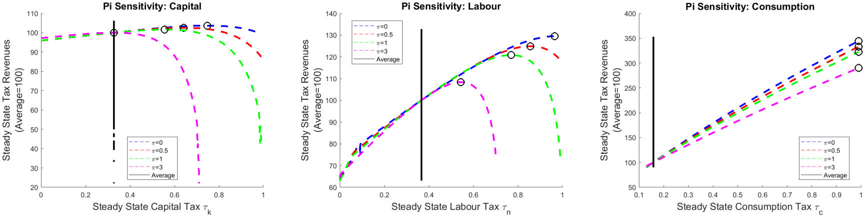


Figure 12: Sensitivity Analysis: π

π	τ_k	Maximum Tax Revenues	τ_n	Maximum Tax Revenues	τ_c	Maximum Tax Revenues
0	0.75	103.68	0.96	129.51	0.99	344.5
0.5	0.64	102.53	0.86	124.92	0.99	332.99
1	0.56	101.61	0.77	120.81	0.99	322.58
3	0.33	100	0.54	108.32	0.99	289.99

Table 6: Sensitivity Analysis: π

Takeaways

- Similar impact to an increase in probability of getting caught
- Optimal tax rate on labour falls from 75 per cent to 33 per cent as penalty rises
- Optimal tax rate on labour falls from 96 per cent to 54 percent
- At the same time, tax capacity falls due to disincentivisation of economic activity

Discussion

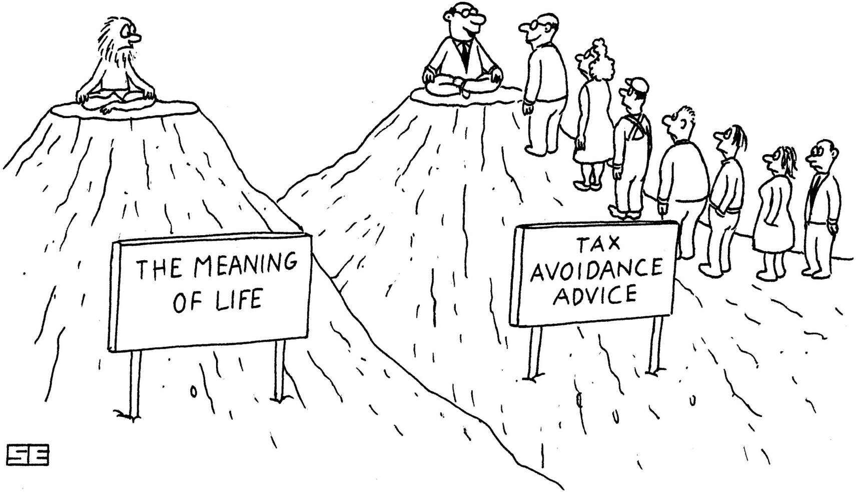
Summary

- Optimal tax rate for capital is close to the average statutory tax rate, while that for labour is higher than the average
- Optimal tax rate on consumption is 99 per cent, in line with Trabandt and Uhlig (2011) due to no tax evasion in consumption
- Increased tax evasion reduces tax capacity as well as optimal tax rates
- Increased audit probabilities and penalties disincentivise economic activity
- Tax revenues may be increased by reducing costs of filing taxes and inducing households to evade less

Work in Progress/Points to Consider

- We aim to endogenise γ, i.e., the proportion of honest taxpayers (alternatively, the proportion of tax evaders) in the model
- We aim to look at the impact of digitisation of tax payments on the model and optimal tax rates
- Mendoza et al. (1994) provide formulae to construct effective tax rates; however, some data not available for India, need some other method to construct effective tax rates
- We aim to conduct a Bayesian estimation of the parameters

Thank You!



Appendix A: Data Collection

Data Sources

- **Control of Corruption Indicator**: Collected from the World Development Indicators database of World Bank; Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests; estimate ranges from approximately -2.5 to 2.5
- **Government Effectiveness**: Collected from the World Development Indicators database of World Bank; Government Effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies; estimate ranges from approximately -2.5 to 2.5

Appendix

Data Sources

- **Tax Revenue as a percentage of GDP**: Collected from the World Development Indicators database of World Bank; Tax revenue refers to compulsory transfers to the central government for public purposes. Certain compulsory transfers such as fines, penalties, and most social security contributions are excluded. Refunds and corrections of erroneously collected tax revenue are treated as negative revenue
- **Hours Taken to File Taxes**: Collected from the Doing Business database of World Bank; The time to comply with tax laws measures the time taken to prepare and pay three major types of taxes and contributions: the corporate income tax, value added or sales tax and labor taxes, including payroll taxes and social contributions

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Appendix B: First-Order Conditions and Balanced Growth Path

First-Order Conditions: Ricardian Households

The Ricardian households first decide how much of the type R and type NR goods to consume, and then decide on the aggregate consumption, labour, investment and bond-holdings

Stage 1

$$max_{c^r_{r,t},c^r_{nr,t}} c^r_t = [a_r^{\frac{1}{\epsilon_r}} (c^r_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1 - a_r)^{\frac{1}{\epsilon_r}} (c^r_{nr,t})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{\epsilon_r}{\epsilon_r - 1}}$$

s. t. $(1 + \tau^c_t)(p^r_t c^r_{r,t} + p^{nr}_t c^r_{nr,t}) = M$

We get the following FOCs:-

$$c^r_{r,t} = a_r(\frac{p^r_t}{P^r_t})^{-\epsilon_r} c^r_t = a_r(T^r_t)^{-\epsilon_r} c^r_t$$

$$c^r_{nr,t} = (1 - a_r)(\frac{p^{nr}_t}{P^r_t})^{-\epsilon_r} c^r_t = (1 - a_r)(T^{nr}_t)^{-\epsilon_r} c^r_t$$

where $P^r_t = [a_r(p^r_t)^{1-\epsilon_r} + (1 - a_r)(p^{nr}_t)^{1-\epsilon_r}]^{\frac{1}{1-\epsilon_r}}$ is the aggregate price faced by Ricardian consumers for their consumption bundle

such that $P^r_t c^r_t = p^r_t c^r_{r,t} + p^{nr}_t c^r_{nr,t}$

T^r_t and T^{nr}_t represent price ratios Back

First-Order Conditions: Ricardian Households

Stage 2

The representative Ricardian household's maximisation problem is as follows:-

$$max_{c_t^r, n_t^r, k_t, b_t} L = E_0 \sum_{t=0}^{\infty} \beta^t [u(c_t^r, n_t^r) + \vartheta(g_t) + \lambda[(1+\tau_t^c)c_t^r + k_t - (1-\delta)k_{t-1} + b_t - (1-\gamma)[(1-\mu)w_t^r n_t^r + \mu(1-\tau_t^n(1+\pi\nu))w_t^r n_t^r] - \gamma(1-\tau_t^n)w_t^r n_t^r - (1-\gamma)[(1-\mu)(d_t-\delta)k_{t-1} + \mu(1-\tau_t^k(1+\pi\nu))(d_t-\delta)k_{t-1}] - \gamma(1-\tau_t^k)(d_t-\delta)k_{t-1} - \delta k_{t-1} - R_t^b b_{t-1} - s_t - \Pi_t^r]]$$

The first-order conditions are:-

$$\lambda_t = \frac{u'_{c^r}}{(1+\tau_t^c)}$$

$$\lambda_t = \frac{-u'_{n^r}}{\{1-\tau_t^n[\gamma + (1-\gamma)\mu(1+\pi\nu)]\}w_t^r}$$

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First-Order Conditions: Ricardian Households

where
$u'_{c^r}(c_t^r, n_t^r) = \frac{1}{(c_t^r)^\eta}[1 - \kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}]^\eta$
$u'_{n^r}(c_t^r, n_t^r) = -\eta\kappa^r(c_t^r)^{1-\eta}(1+\frac{1}{\psi})(n_t^r)^{\frac{1}{\psi}}[1 - \kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}]^{\eta-1}$

$$\lambda_t = \beta\lambda_{t+1}[1 + (1-\gamma)(1-\mu\tau_{t+1}^k(1+\pi\nu))(d_{t+1}-\delta) + \gamma(1-\tau_{t+1}^k)(d_{t+1}-\delta)]$$

$$R_{t,t+1}^b = \frac{\lambda_t}{\beta\lambda_{t+1}}$$

Combining the above two equations, we have:-

$$R_{t,t+1}^b = 1 + (1-\gamma)(1-\mu\tau_{t+1}^k(1+\pi\nu))(d_{t+1}-\delta) + \gamma(1-\tau_{t+1}^k)(d_{t+1}-\delta)$$

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First-Order Conditions: Non-Ricardian Households

The representative non-Ricardian household's maximisation problem is as follows:-

$$max_{c_t^{nr}, n_t^{nr}} L = E_0 \sum_{t=0}^{\infty} \beta^t [u(c_t^{nr}, n_t^{nr}) + \vartheta(g_t) - \lambda_t [(1+\tau_t^c) c_t^{nr} - w_t^{nr} n_t^{nr} - s_t - \Pi_t^{nr}]]$$

The first-order conditions are:-

$$\tilde{\lambda}_t = \frac{u'_{c^{nr}}}{(1+\tau_t^c)} \quad (24)$$

$$\tilde{\lambda}_t = \frac{-u'_{n^{nr}}}{w_t^{nr}} \quad (25)$$

where
$u'_{c^{nr}}(c_t^{nr}, n_t^{nr}) = \frac{1}{(c_t^{nr})^{\eta}}[1 - \kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi}}]^{\eta}$
$u'_{n^{nr}}(c_t^{nr}, n_t^{nr}) = -\eta \kappa^{nr} (c_t^{nr})^{1-\eta} (1+\frac{1}{\psi})(n_t^{nr})^{\frac{1}{\psi}} [1 - \kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi}}]^{\eta-1}$ Back

Aggregate Budget Constraint for the Economy

Combining the Ricardian and non-Ricardian budget constraints, multiplying them with the respective proportion of Ricardian and non-Ricardian households (i.e. $1-\omega$ and ω respectively), we get:-

$$\begin{aligned}(1-\omega)(1+\tau_t^c)c_t^r + \omega(1+\tau_t^c)T_t^{nr}c_t^{nr} + (1-\omega)(x_t+b_t) = \\ (1-\omega)(w_t^r n_t^r + d_t k_{t-1}) - (1-\omega)\{[(\gamma+(1-\gamma)\mu(1+\pi\nu))\tau_t^n]w_t^r n_t^r + \\ [(\gamma+(1-\gamma)\mu(1+\pi\nu))\tau_t^k](d_t-\delta)k_{t-1}]\} + (1-\omega)R_t^b b_{t-1} + (1-\omega)s_t \\ +\omega T_t^{nr} w_t^{nr} n_t^{nr} + \omega s_t\end{aligned}$$

Define
$C_t = (1-\omega)(1+\tau_t^c)c_t^r + \omega(1+\tau_t^c)T_t^{nr}c_t^{nr}$
$Y_t = (1-\omega)(w_t^r n_t^r + d_t k_{t-1}) + \omega T_t^{nr} w_t^{nr} n_t^{nr}$
and using
$s_t = (1-\omega)(b_t - R_t^b b_{t-1}) + T_t - g_t$
We get

$$C_t + (1-\omega)x_t + g_t = Y_t$$

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Balanced Growth Path

Along the balanced growth path, government spending, government debt and assets grow at the same rate, i.e., the growth factor of type R output

$$g_t = (\zeta^r)^t \bar{g} \tag{26}$$

$$b_{t-1} = (\zeta^r)^t \bar{b} \tag{27}$$

Thus, the government budget constraint can be rewritten as:-

$$s_t = (\zeta^r)^t \bar{b}(\zeta^r - R_t^b) + T_t - (\zeta^r)^t \bar{g} \tag{28}$$

Balanced Growth Path

Capital to Output Ratio

From the household optimality conditions:-

$$R^b_{t,t+1} = 1 + (1-\gamma)(1-\mu\tau^k_{t+1}(1+\pi\nu))(d_{t+1}-\delta) + \gamma(1-\tau^k_{t+1})(d_{t+1}-\delta)$$

$$\implies R^b_{t,t+1} - 1 = (1-\gamma)(1-\mu\tau^k_{t+1}(1+\pi\nu))(d_{t+1}-\delta) + \gamma(1-\tau^k_{t+1})(d_{t+1}-\delta)$$

Substituting for d_t from the Ricardian firm optimality condition:-

$$R^b_{t,t+1} - 1 = (1-\gamma)(1-\mu\tau^k_{t+1}(1+\pi\nu))(\theta\frac{y^r_{t+1}}{k_t}-\delta) + \gamma(1-\tau^k_{t+1})(\theta\frac{y^r_{t+1}}{k_t}-\delta)$$

gives along the balanced growth path:-

$$\overline{k/y^r} = [\frac{\overline{R^b}-1}{\theta[1-\overline{\tau^k}(\gamma+(1-\gamma)\mu(1+\pi\nu))]} + \frac{\delta}{\theta}]^{-1}$$

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Balanced Growth Path

$\overline{R^b}$ is as follows:-
From household optimality conditions:-

$$\lambda_t = \frac{u'_{c^r}}{(1+\tau_t^c)p_t^r}$$

$$\implies \frac{\lambda_t}{\lambda_{t+1}} = \frac{u'_{c^r}(c_t^r, n_t^r)}{u'_{c^r}(c_{t+1}^r, n_{t+1}^r)} \frac{(1+\tau_{t+1}^c)}{(1+\tau_t^c)}$$

Using $u'_{c^r}(c_t^r, n_t^r) = \frac{1}{(c_t^r)^\eta}[1-\kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}]^\eta$
and, $c_{t+1}^r = \zeta c_t^r, \tau_t^c = \tau_{t+1}^c$ and $n_{t+1} = n_t$ along the balanced growth path we get

$$\overline{R^b} = \frac{\zeta^\eta}{\beta}$$

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Balanced Growth Path

Consumption to Output Ratio (Ricardian)

Using optimality conditions for Ricardian households, we have

$$\frac{\frac{1}{(c_t^r)^\eta}[1-\kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}]^\eta}{-\eta\kappa^r(c_t^r)^{1-\eta}(1+\frac{1}{\psi})(n_t^r)^{\frac{1}{\psi}}[1-\kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}]^{\eta-1}} = \frac{-(1+\tau_t^c)}{[1-\tau_t^n(\gamma+(1-\gamma)\mu(1+\pi\nu))]w_t^r}$$

$$\implies c_t^r = [\frac{[1-\tau_t^n(\gamma+(1-\gamma)\mu(1+\pi\nu))]w_t^r}{(1+\tau_t^c)}][\frac{1-\kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}}{\eta\kappa^r(1+\frac{1}{\psi})(n_t^r)^{\frac{1}{\psi}}}]$$

Dividing LHS and RHS y_t^r and using equation (13):-

$$\frac{c_t^r}{y_t^r} = [\frac{[1-\tau_t^n(\gamma+(1-\gamma)\mu(1+\pi\nu))](1-\theta)}{(1+\tau_t^c)}][\frac{1-\kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}}{\eta\kappa^r(1+\frac{1}{\psi})(n_t^r)^{1+\frac{1}{\psi}}}]$$

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Balanced Growth Path

$$\implies \alpha^r \frac{c_t^r}{y_t^r} = \frac{1 - \kappa^r(1-\eta)(n_t^r)^{1+\frac{1}{\psi}}}{\eta\kappa^r(n_t^r)^{1+\frac{1}{\psi}}}$$

where $\alpha^r = \frac{(1+\tau_t^c)(1+\frac{1}{\psi})}{[1-\tau_t^n(\gamma+(1-\gamma)\mu(1+\pi\nu))](1-\theta)}$

Expanding the numerator,

$$\alpha^r \frac{c_t^r}{y_t^r} = 1 - \frac{1}{\eta} + (\eta\kappa^r(n_t^r)^{1+\frac{1}{\psi}})^{-1}$$

Thus, along the balanced growth path:-

$$\overline{\alpha^r}(\overline{c^r/y^r}) = 1 - \frac{1}{\eta} + (\eta\kappa^r(\overline{n}^r)^{1+\frac{1}{\psi}})^{-1}$$

where $\overline{\alpha^r} = \frac{(1+\overline{\tau^c})(1+\frac{1}{\psi})}{[1-\overline{\tau^n}(\gamma+(1-\gamma)\mu(1+\pi\nu))](1-\theta)}$ ▸ Back

Balanced Growth Path

Consumption to Output Ratio (Non-Ricardian)

Using household optimality conditions for non-Ricardian households, we have

$$\frac{\frac{1}{(c_t^{nr})^\eta}[1-\kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi}}]^\eta}{-\eta\kappa^{nr}(c_t^{nr})^{1-\eta}(1+\frac{1}{\psi})(n_t^{nr})^{\frac{1}{\psi}}[1-\kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi}}]^{\eta-1}} = \frac{-(1+\tau_t^c)}{w_t^{nr}}$$

$$\implies c_t^{nr} = \frac{w_t^{nr}}{(1+\tau_t^c)}[\frac{1-\kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi}}}{\eta\kappa^{nr}(1+\frac{1}{\psi})(n_t^{nr})^{\frac{1}{\psi}}}]$$

Dividing LHS and RHS y_t^{nr} and using (15):-

$$\frac{c_t^{nr}}{y_t^{nr}} = [\frac{1}{(1+\tau_t^c)(1+\frac{1}{\psi})}][\frac{1-\kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi}}}{\eta\kappa^{nr}(n_t^{nr})^{1+\frac{1}{\psi}}}]$$

▸ Back

Balanced Growth Path

$$\implies \alpha^{nr} \frac{c_t^{nr}}{y_t^{nr}} = \frac{1 - \kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi}}}{\eta\kappa^{nr}(n_t^{nr})^{1+\frac{1}{\psi}}}$$

where $\alpha^{nr} = (1+\tau_t^c)(1+\frac{1}{\psi})$

Expanding the numerator,

$$\alpha^{nr} \frac{c_t^{nr}}{y_t^{nr}} = 1 - \frac{1}{\eta} + (\eta\kappa^{nr}(n_t^{nr})^{1+\frac{1}{\psi}})^{-1}$$

Thus, along the balanced growth path:-

$$\overline{\alpha^{nr}}(\overline{c^{nr}/y^{nr}}) = 1 - \frac{1}{\eta} + (\eta\kappa^{nr}(\overline{n^{nr}})^{1+\frac{1}{\psi}})^{-1}$$

where $\overline{\alpha^{nr}} = (1+\overline{\tau^c})(1+\frac{1}{\psi})$ Back

Balanced Growth Path

Labour Choice (Ricardian)

Substituting for b_t by $\zeta^r b_{t-1}$, Π_t^r by Ricardian firm profits, x_t by 2, we get the following:-

$$\begin{aligned}(1+\tau_t^c)c_t^r + k_t - &(1-\delta)k_{t-1} + \zeta^r b_{t-1} = \\ &(1-\gamma)[(1-\mu)w_t^r n_t^r + \mu(1-\tau_t^n(1+\pi\vartheta))w_t^r n_t^r] + \\ &\gamma(1-\tau_t^n)w_t^r n_t^r + (1-\gamma)[(1-\mu)(d_t-\delta)k_{t-1} + \\ &\mu(1-\tau_t^k(1+\pi\vartheta))(d_t-\delta)k_{t-1}] + \gamma(1-\tau_t^k)(d_t-\delta)k_{t-1} + \\ &\delta k_{t-1} + R_t^b b_{t-1} + s_t + y_t^r - -w_t^r n_t^r - d_t k_{t-1}\end{aligned}$$

Substituting for k_t by $\zeta^r k_{t-1}$ and after some basic algebra, we get:-

$$\begin{aligned}(1+\tau_c^t)c_t^r =& y_t^r + s_t + b_{t-1}(R_t^b - \zeta^r) - (\zeta^r - 1 + \delta)k_{t-1} - \\ &[\gamma + (1-\gamma)\mu(1+\pi\nu)][\tau_t^n w_t^r n_t^r + \tau_t^k(d_t-\delta)k_{t-1}]\end{aligned}$$

▸ Back

Balanced Growth Path

Dividing through by y_t^r, we have:-

$$\frac{c_t^r}{y_t^r} = \frac{1}{(1+\tau_t^c)}\{1 + \frac{s_t}{y_t^r} + \frac{b_{t-1}}{y_t^r}(R_t^b - \zeta^r) - (\zeta^r - 1 + \delta)\frac{k_{t-1}}{y_t^r} - [\gamma + (1-\gamma)\mu(1+\pi\nu)][\tau_t^n w_t^r \frac{n_t^r}{y_t^r} + \tau_t^k (d_t - \delta)\frac{k_{t-1}}{y_t^r}]\}$$

Further, from the Ricardian sector production function, we have:-

$$y_t^r = (A^r)^t k_{t-1}^{\theta}(n_t^r)^{1-\theta}$$
$$\implies (y_t^r)^{\theta}(y_t^r)^{1-\theta} = (A^r)^t k_{t-1}^{\theta}(n_t^r)^{1-\theta}$$
$$\implies (y_t^r)^{1-\theta} = (A^r)^t \frac{k_{t-1}^{\theta}}{(y_t^r)^{\theta}}(n_t^r)^{1-\theta}$$
$$\implies y_t^r/n_t^r = (\zeta^r)^t (k_{t-1}/y_t^r)^{\frac{\theta}{1-\theta}}$$
$$\implies \overline{y^r}/\overline{n^r} = (\zeta^r)\overline{k/y^r}^{\frac{\theta}{1-\theta}}$$

along the balanced growth path

Back

Balanced Growth Path

Thus, along the balanced growth path:-

$$\overline{c^r/y^r} = \chi + \gamma \frac{1}{\overline{n^r}}$$

where:-

$\chi =$

$\frac{1}{(1+\overline{\tau^c})}\{1-(\zeta^r-1+\delta)\overline{k/y^r}-[\gamma+(1-\gamma)\mu(1+\pi\nu)][\overline{\tau^n w^r}\frac{(\overline{k/y^r})^{\frac{-\theta}{1-\theta}}}{\zeta^r}+\overline{\tau^k}(\overline{d}-\delta)\overline{k/y^r}]\}$

$\gamma = \frac{1}{(1+\overline{\tau^c})}\frac{(\overline{k/y^r})^{\frac{-\theta}{1-\theta}}}{\zeta^r}[\overline{b}(\overline{R^b}-\zeta^r)+\overline{s}]$

Substituting for $\overline{c^r/y^r}$ from 19, we have:-

$$\overline{\alpha^r}(\chi + \gamma \frac{1}{\overline{n^r}}) = 1 - \frac{1}{\eta} + (\eta\kappa^r(\overline{n}^r)^{1+\frac{1}{\psi}})^{-1}$$

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Balanced Growth Path

Labour Choice (Non-Ricardian)

Using the budget constraint for non-Ricardian households from 8, and since profits are zero in equilibrium, we have:-

$$(1+\tau_t^c)T_t^{nr}c_t^{nr} = T_t^{nr}w_t^{nr}n_t^{nr} + s_t + \Pi_t^{nr}$$

$$\implies c_t^{nr} = \frac{T_t^{nr}w_t^{nr}n_t^{nr} + s_t}{T_t^{nr}(1+\tau_t^c)}$$

Dividing through by $T_t^{nr}y_t^{nr}$, we have:-

$$\frac{c_t^{nr}}{y_t^{nr}} = \frac{1 + \frac{s_t}{T_t^{nr}y_t^{nr}}}{(1+\tau_t^c)}$$

▸ Back

Balanced Growth Path

Thus, along the balanced growth path:-

$$\overline{c^{nr}/y^{nr}} = \frac{1}{(1+\overline{\tau^c})}[1+\overline{s}/\overline{(y^{nr}}\overline{T^{nr}})]$$

Substituting for $\overline{c^{nr}/y^{nr}}$ from 20, we have:-

$$\overline{\alpha^{nr}}\frac{1}{(1+\overline{\tau^c})}[1+\overline{s}/\overline{(y^{nr}}\overline{T^{nr}}] = 1-\frac{1}{\eta}+(\eta\kappa^{nr}(\overline{n}^{nr})^{1+\frac{1}{\psi}})^{-1}$$

▸ Back

Laffer Curve

From the tax revenue equation 16, we have:-

$$T_t = \tau_t^c[\omega c_t^{nr} + (1-\omega)c_t^r] + (1-\omega)[\gamma + (1-\gamma)\mu(1+\pi\nu)][\tau_t^n w_t^r n_t^r + \tau_t^k(d_t-\delta)k_{t-1}]$$

Dividing throughout by y_t^r:-

$$\frac{T_t}{y_t^r} = \tau_t^c((1-\omega)\frac{c_t^r}{y_t^r} + \omega\frac{c_t^{nr}}{y_t^{nr}}\frac{y_t^{nr}}{y_t^r}) + (1-\omega)[\gamma + (1-\gamma)\mu(1+\pi\nu)][\tau_t^n w_t^r \frac{n_t^r}{y_t^r} + \tau_t^k(d_t-\delta)\frac{k_{t-1}}{y_t^r}]$$

Using 12 and 13 provides the BGP equation for the Laffer curve:-

$$L = \frac{\overline{T}}{\overline{y^r}} = \{\overline{\tau^c}(\omega\overline{(c^{nr}/y^{nr})}\overline{y^{nr}}/\overline{y^r} + (1-\omega)\overline{(c^r/y^r)}) + (1-\omega)[\gamma + (1-\gamma)\mu(1+\pi\nu)][\overline{\tau^n}(1-\theta) + \overline{\tau^k}(\theta - \delta\overline{k/y^r})]\}$$

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