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Abstract

This paper explores the possible ways in which the emerging market and developing economies (EMDEs) can improve their tax-to-GDP ratio using a theoretical framework. We do this using a Laffer curve analysis at the balanced growth path. We develop a closed-economy discrete-time neoclassical growth model with heterogeneous agents, and three sectors: households, firms, and the government. This model is calibrated for a typical EMDE and it incorporates two well-documented features that limit their tax capacity. The first feature we model is the presence of a large proportion of the economy that neither pays nor files taxes. To address this, our model includes heterogeneous agents, represented by Ricardian and non-Ricardian households. Non-Ricardian households belong to the informal sector and are entirely exempt from taxes, while Ricardian households may choose to comply with tax obligations, creating a partially endogenous framework for tax evasion. The second critical feature is the relative weakness of institutions in the EMDEs as compared to the advanced economies (AEs). We incorporate aspects such as the probability of audits, penalties for evasion, and the culture of corruption in a minimalist way to capture the essence of the realities of weak institutions. We derive the expression for the Laffer curve for three types of taxes: the labour income tax, the capital income tax, and the consumption tax. We find that the fiscal policies attuned towards bringing a higher percentage of agents under the ambit of tax collection - despite households evading taxes - significantly boost the tax revenues. The model clearly shows that countries with weaker institutions will have a lower tax capacity, as any increase in the tax rates reduces tax compliance and increases tax evasion. Finally, reducing the income tax exemptions, decreasing the share of informal sector firms and employees, and strengthening the institutional quality are essential for improving the fiscal space in the EMDEs. To our knowledge, no coherent neoclassical growth model exists in the literature that effectively captures these features within EMDEs.

Keywords: Laffer curve, Optimal taxes, Growth models, Heterogeneous Agents, Institutions, Tax Evasion

JEL Code: E02, E13, E62, H21, H26

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1. Introduction

Fiscal policy is an imperative tool used by governments across the globe to influence the economy to achieve desired results. The role of public spending is even more crucial for the developing economies as the government provides infrastructure to increase productivity and attract private investment, provides education, healthcare services at affordable prices, and a social safety net to the vulnerable sections of the society (Aschauer (1989), Ravallion (2009) and Sen (2000)). According to IMF (2024), gross debt as a percentage of GDP (Gross Domestic Product) has crossed 100 percent for the advanced economies (AEs) and is growing rapidly in the emerging market and developing economies (EMDEs). Fiscal consolidation is thus extremely important over the coming years. This paper attempts to quantify the possible ways in which the EMDEs can improve their tax-to-GDP ratio using a theoretical framework. About 60 percent of the government expenditure was sourced from the tax revenues for both AEs and EMDEs between 2000-2018 (Ortiz-Ospina and Roser (2016)). Using the database provided by World Bank (2024d), we observe that throughout 2000-2018, the tax to GDP ratio has been around 20-22 percent for the set of AEs, while it is around 14-16 percent for the EMDEs. Besley and Persson (2014) in their paper show that developing countries have had a low ratio of tax revenue to GDP due to a large informal sector, weak political institutions, high corruption perception index and poor tax-compliance norms. Piketty and Qian (2009) pointed out how the adaption of exemptions has led to a constant tax to GDP ratio in India. We also observe in the data that EMDEs excessively depend on the indirect tax revenues rather than the direct tax revenues, unlike AEs. It is well documented in the literature that the indirect taxes are inequitable and biased against the economically weaker sections of the society (Heathcote (2005), Schechtl (2024)). One possible reason for this observation is that the EMDEs are unable to generate direct tax revenues, as a low proportion of individuals pay direct taxes, and because of this, the government cannot increase tax rates beyond a point. In India, about 74 million people filed for income tax returns in the assessment year 2022-23, of which 51.6 million people, or 70 percent, had zero tax liability. This implies that just 22.4 million people paid income tax in the assessment year 2022-2023 (Print (2023)). This is only 1.6 percent of the total population and about 2.54 percent of the working-age population. The present study focuses on how the EMDEs can improve their fiscal space through tax revenue mobilization with a focus on direct tax collection.

Direct tax revenues can be increased using the following three possible channels in the EMDEs. The first channel is by increasing the tax rates. Although taxes are distortionary as they lead to social welfare losses, they are the major source of government spending (Feldstein (1999), Feldstein (2008), Blow and Preston (2002)).[1] The rise in tax rates can lead to an increase in the tax revenues but on the margin, it also disincentivizes economic activity by agents in the economy, and they may find leisure more desirable. This is the *labour supply channel* (Heckman (1993), Feldstein (1995), Trabandt and Uhlig (2011)). Additionally, the agents might get encouraged to evade taxes, which would also lead to a fall in the tax revenues. This is the *tax compliance channel*

[1] The focus of this paper is on income taxes (direct taxes) and not on the consumption taxes (indirect taxes) for reasons discussed later.

(Fisman and Wei (2004), Papp and Takáts (2008)). Laffer (2004), in his popular work, summarizes the relationship between tax rate and tax revenues. Figure 1 shows a typical Laffer curve where the relationship between tax rates and tax revenues is positive initially, but for higher tax rates, the tax revenue collection falls. When the negative effect of an increase in tax rates dominates the positive one, it is called *Laffer effect*. The cut-off point at the peak of the Laffer curve provides the optimal tax rates. This implies that an increase in the tax rate may not necessitate an increase in tax revenues. The curvature of the Laffer curve and the position of optimal tax rates would be different for every country, as it would depend on various features of the economy. How early the inverse relationship between tax rate and tax revenues hits an economy would also be determined by various features of the economy including the size of the informal sector (Alba and McKnight (2022)), the level of technological development (Moloi et al. (2020)), the quality of institutions, and the quality of administration (Papp and Takáts (2008), Besley and Persson (2014)).[2] The second channel to improve tax collection is improving the tax compliance channel by reducing tax evasion, which shifts the Laffer curve upward. This would imply that tax revenues increase for all the tax rates. Some of these measures would include strengthening the institutional quality with increased tax auditing, effective punitive action if caught evading, improving the compliance norms and reducing the administrative costs of filing taxes (Kleven et al. (2011), Advani et al. (2023), Banerjee et al. (2022), Papp and Takáts (2008), Besley and Persson (2014), Aruoba (2021)).[3] The third channel is by increasing the tax base. This is important because EMDEs are characterized by large agricultural sectors that are exempted from paying income taxes and a large informal sector, which is cloaked from the system and is thus difficult to tax (La Porta and Shleifer (2014), Alba and McKnight (2022)). This channel also feeds into the tax compliance channel. An increase in the tax base also shifts the Laffer curve upwards. Although in the literature, papers study the features associated with each of these channels individually, there does not exist a comprehensive theoretical framework to capture all three channels discussed above and study the possibility of increasing the tax revenues. The present paper fills this gap. We add the above highlighted features of the EMDEs into the theoretical framework in a minimalistic way to understand and quantify how the EMDEs can improve their tax mobilisation capacity.

[INSERT FIGURE 1]

[2] Many empirical studies have been conducted to estimate the Laffer curve. Early papers such as Buchanan and Lee (1982) and Wanniski (1978) discuss the political economy of the Laffer curve, and how the government can make the mistake of underestimating the economic effect (and overestimating the arithmetic), and end up with the tax rates on the prohibitive side of the Laffer curve. Hsing (1996) conducts a time-series analysis for the years 1959-91 for the US, and estimates Laffer curve effects, with optimal tax rates in the range of 32.67 percent to 35.21 percent. Ferreira-Lopes et al. (2020) conduct a similar analysis for Eurozone member countries. Clausing (2007) analyses the variation in the corporate tax revenues across OECD countries between 1979 and 2002. The author finds evidence in support of a Laffer curve of corporate tax revenues with a peak tax rate of 33 percent for the whole sample. These papers estimate Laffer curves and optimal tax rates in cross-country analyses and compare them to the prevailing tax rates. A similar empirical work is limited for EMDEs due to data constraints. Latif et al. (2019) and Gupta and Gupta (2019) have estimated Laffer curves for Pakistan and India respectively.

[3] Alm and Martinez-Vazquez (2003) look at the impact of tax enforcement as well as social norms regarding tax compliance on tax evasion.

We construct a closed-economy discrete-time neoclassical growth model with heterogeneous agents, and three sectors: households, firms, and the government. To derive a micro-founded expression for the Laffer curve, we adapt the basic structure of our model from the seminal paper by Trabandt and Uhlig (2011). The authors construct a neoclassical growth model and derive an analytical expression for the Laffer curve and later estimate it for the US and the EU-14. The authors find that the US can increase tax revenues by 30 percent and the EU-14 by 8 percent by raising labour income taxes. Moreover, by raising capital income taxes, the US can raise tax revenues by 6 percent and the EU-14 by 1 percent.[4] Nutahara (2015) borrows from Trabandt and Uhlig (2011) and conducts a similar exercise for Japan. The author finds that the optimal rates for labour and capital income tax are in the range of 50-60 percent and that the consumption tax Laffer curve does not peak. Lozano-Espitia and Arias-Rodríguez (2021) conduct a similar analysis for the Latin American countries for period 1994-2017 and find similar results i.e the optimal capital and labour tax rates are in the range of 50-60 percent. On consumption taxes, all of these papers indicate that the Laffer curve does not peak, i.e., the tax revenue on consumption always increases with an increase in the tax rate. We also do the Laffer curve analysis for the direct taxes; labour income tax, and capital income tax, and indirect taxes; consumption tax. As we use a model structure similar to Trabandt and Uhlig (2011), we also find that the consumption tax Laffer curves do not peak, but the focus of this paper is on direct taxes and not indirect taxes. In the above-mentioned papers, the Laffer effect is generated only because of the labour supply channel.

To add the tax compliance channel, we adapt a few model features from Papp and Takáts (2008). The authors build a simple model to analyze the impact of the quality of government administration and the culture of corruption on the tax compliance for an EMDE. They show that tax cuts can lead to a higher tax revenues by improving tax compliance. The paper generates the Laffer effect only through the tax compliance channel. They do their analysis specifically for the Russian economy. The authors find that for Russia, the introduction of a flat income tax rate combined with tax exemptions on income led to an increase in tax revenues. The authors show that tax cuts can lead to a higher tax revenue by improving the tax compliance. We add features from this model as follows. First, we endogenize tax evasion by some households, which is a prominent feature in the EMDEs. We capture the quality of tax administration through the introduction of the probability of getting audited if caught post-tax evasion. We also allow for a punitive action by the government if a household is caught evading taxes in the form of monetary penalty payments. The model also features the norm of tax compliance in an economy and the alignment of each household with this norm in a minimalistic way.

Alba and McKnight (2022) introduces tax evasion in a different way. The authors build upon Trabandt and Uhlig (2011) by adding the informal sector to the economy, thus allowing for the possibility of a tax evasion. As a result, individuals can substitute between the formal and the informal goods, as well as the formal and the informal employment, and thus avoid paying taxes.

[4] Trabandt and Uhlig (2011) extend the analysis by allowing for monopolistic competition, as well as conducting the analysis using more recent data.

They run calibrations for the Latin American countries and estimate the optimal tax rates in the range of 30-40 percent from the model with the informal economy, and 60-65 percent for the model with only the formal sector. The peak of the Laffer curve also varies with the substitutability between the formal and the informal goods. If they are highly substitutable, optimal tax rates fall, as expected. The authors also find that the consumption tax Laffer curve does, in fact, peak when the informal sector is considered.[5] Heterogeneity in the EMDEs is thus a very important feature to understand how tax capacity is limited by a large mass of the economy that does not pay taxes.

Based on the facts discussed later, we believe that there are three types of individuals who do not pay taxes in the EMDEs. First, the individuals who are availing tax exemptions including exemptions to certain sectors like agricultural incomes and exemptions to individuals whose incomes are below a certain threshold. The second are those who work in the informal sector (both firms and employees) and the underground economy which is cloaked from the tax payment systems. There is a large overlap between the second and the first, which comes from the informal employment incomes, which are low and thus are exempted. The third are those individuals who are tractable by the government system but decide to evade despite the risk of getting caught. To capture this, we introduce heterogeneity by constructing two kinds of households: Ricardian and non-Ricardian households. The Ricardian households have to pay taxes to the government. The non-Ricardian households do not pay income taxes either because they are exempt or they are cloaked from the system completely. The Ricardian households can choose to pay or evade income taxes based on the state that gives them higher utility. These households also save and invest. Taxes on consumption are, however, paid by both kinds of households. This is because consumption taxes are indirect taxes and are paid by everyone as they are included in the commodity prices. This makes tax evasion partially endogenous. There is heterogeneity on the firm side as well. Firms owned by Ricardian households produce using both capital and labour inputs, whereas firms owned by non-Ricardian households produce using only labour input. We calibrate the share of non-Ricardian in the EMDEs to be 75 percent following Elgin et al. (2021b) later in the model. Additionally, from our baseline model we find that about 46.1 percent of the Ricardian households and 11.5 percent of total households choose to evade taxes, respectively. This implies that approximately 86.5 percent of the households in the model economy do not pay taxes.[6] We now present some stylized facts for the AEs and the EMDEs relevant to the present study.

1.1. Some stylized facts

In this section, we present a few stylized facts on the AEs and the EMDEs from the data as discussed in the previous section. Figure 2 plots the aggregated annual data from World Bank (2024d) on

[5] Busato and Chiarini (2013) have conducted a similar exercise, by including the underground economy in a dynamic general equilibrium model, using calibrations for Italy. They find that the Laffer curve with the shadow economy (a proxy for tax evasion) is below that for the economy without tax evasion. However, optimal tax rates are quite similar in the two settings.

[6] This is consistent with Dholakia (2022) which estimates that between 2011-12 and 2017-18, around 8-16 percent of the total population in India was evading personal income tax.

tax-to-GDP ratio from 1998-2021 for the EMDEs, the AEs, and the global average.[7] We use data for 195 countries of which 40 are AEs and 155 are EMDEs.[8] We observe that throughout 1998-2021, the tax revenue as a percentage of GDP has been around 20-22 percent for the set of AEs, while it is around 14-16 percent for the EMDEs. The EMDEs are below the simple global average of 16-17 percent. The gap was around 8 percent in the early 2000s and has come down to 6 percent post the global financial crisis, but the gap still remains. Next, Figure 3 plots the ratio of direct tax revenues to indirect tax revenues for the AEs and the EMDEs from 2000-2021. For the AEs the ratio is above 1 and lies between 1.4-1.5, and for the EMDEs it has stayed around 0.5. This clearly shows the excessive dependence of the EMDEs on indirect tax revenues, which are regressive as mentioned earlier, and their inability to raise tax revenues through the direct tax collection.

[INSERT FIGURE 2 AND FIGURE 3]

The next set of empirical facts that we present in Figures 4, 5 and 6 give us a glance into the norms for tax compliance and quality of institutions in the AEs and the EMDEs. Figure 4 presents the values of the 'Control of Corruption' indicator between 1998 and 2022, for the EMDEs, the AEs and the global average.[9] The average value of this indicator has stayed around -0.4 over the years for the EMDEs, while it is around 1.2 for the AEs. This is an important indicator of perceived norms of tax compliance in an economy. A higher positive value means that the economy is able to control the corruption and has higher norms of tax compliance, thus lower tax evasion. Since the value for the EMDEs is negative, it indicates that the norms of tax compliance are low and thus tax evasion is higher as compared to the AEs. This inference is consistent with Bethencourt and Kunze (2020) who find a negative relationship between economic growth and tax evasion. The authors construct an OLG model with an element of tax morale or social norm in favour of tax compliance and observe that this leads to a complementarity between evasion of the labour and capital taxes.

[INSERT FIGURE 4]

Figure 5 provides values of the Government Effectiveness indicator for the EMDEs, the AEs and the global average.[10] The AEs fare better with the value of this indicator being around 1.2-1.3

[7] World Bank (2024d) defines tax revenue as 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.

[8] Country-wise data is available with the World Bank. We have aggregated countries based on data availability, as per IMF's classification of AEs and EMDEs. The detailed list of countries is provided in the Data Appendix Section B.B.1.

[9] World Bank (2024d) defines the Control of Corruption indicator as 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 gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5.

[10] World Bank (2024d) defines Government Effectiveness as 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

over the years, whereas the EMDEs average around a value of -0.4. Country-specific elements like corruption and the quality of governance have an impact on tax collections and tax compliance (Laffer (2004), Besley and Persson (2014)). Figure 6 shows the number of hours taken by firms in a country to file taxes in a year between 2014-2020.[11] While it has fallen from 284.5 hours to 256.7 hours for the set of the EMDEs, it is still high as compared to the average for the AEs. In fact, it has fallen for the AEs as well but the gap remains the same. This indicates the high level of complexity and bureaucratic delays involved in the tax administration of the EMDEs. These features impact the tax capacity of the economy by influencing tax compliance (Besley and Persson (2014), Witte and Woodbury (1985), Papp and Takáts (2008)).

[INSERT FIGURE 5 AND FIGURE 6]

The EMDEs are also characterized by a large share of the population that does not pay taxes. This includes individuals that are tax exempt and those who are a part of the informal or shadow economy. According to Medina and Schneider (2021), the size of the informal economy has been larger for the EMDEs at 28-35 percent, than for the AEs at 14-18 percent, throughout 1991-2017. Even though the size of the informal economy has fallen across the world, the gap between the EMDEs and the AEs remains, and this poses a challenge to tax collections for the growing EMDEs (Kodila-Tedika and Mutascu (2013), Bentum-Ennin and Adu (2024)). Evidence also exists on the sizable tax exemptions that are provided in the EMDEs.[12] This includes exemptions given to the agricultural income. Given the large share of agriculture sector in output and employment in the EMDEs as compared to the AEs, these tax exemptions can potentially lead to a significant loss of the tax revenues. Although many OECD countries also provide tax benefits on the agricultural activities (OECD (2020)), the EMDEs face additional challenges, such as the measurement of agricultural income as well as political considerations while trying to tax agriculture (Khan (2001)). The comptroller and auditor general (CAG) of India found that out of about half a million people who were granted exemptions on the agricultural income in India in 2013-14, more than 50 percent of the cases were not properly verified, i.e., there were missing proper documents and records (Bhattacharjee (2020)). This makes the exemption system prone to misuse. Apart from agriculture, we also observe exemptions on the income tax in both the EMDEs and the AEs. Countries such as India, Austria, Germany, Australia, Pakistan, and Thailand provide tax exemptions on the income tax up to a certain income threshold (PWC (2024)). On average, as of 2021, over 40 percent of the population in the EMDEs earned less than 6.85 USD per day, while this estimate was around

implementation, and the credibility of the government's commitment to such policies. Estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5.

[11] World Bank (2024a) defines 'Hours Taken to File Taxes' as 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 labour taxes, including payroll taxes and social contributions.

[12] Jeff Chelsky (2023) discusses the impact of tax exemptions on tax revenue collections. A reintroduction of tax exemptions in Pakistan before 2018 elections led to a fall in tax revenues from 12.9 percent to 11.6 percent of GDP.

1 percent percent in the AEs. Additionally, only about 6 percent of the population in the EMDEs earned more than 40 USD per day, whereas more than half of the population in the AEs earned this amount. Thus, such tax exemptions impact EMDEs more than the AEs, since a large percentage of population in the EMDEs is at the lower end of the income distribution.[13] In this context, it is important to look at the ways to improve tax revenue collection in the EMDEs. To summarize, we observe that the EMDEs fall behind the AEs in the institutional factors and the population share that pays taxes. Both these factors contribute to limiting the tax capacity and the lower tax-to-GDP ratio. We build a neoclassical growth model in the next section and attempt to quantify the possible ways in which the EMDEs can improve their tax-to-GDP ratio using a theoretical framework.
We find that fiscal policies attuned towards bringing a higher percentage of agents under the ambit of tax collection, despite people trying to evade, improve the tax revenues significantly. The tax revenues can increase by 50 percent for both capital and labour taxes in the EMDEs when all the households are Ricardian. The model clearly shows that countries with weaker institutions will have lower tax capacity as any increase in tax rates reduces tax compliance and increases tax evasion. Thus, an improvement in the quality of institutions is imperative to improve the fiscal space for governments in the EMDEs. Additionally, features like tax exemptions and how such exemptions affect the Laffer curve have also not been studied in the literature. This is where the present study contributes to the existing literature.

2. Model

We construct a closed-economy, discrete-time, neoclassical growth model with heterogeneous agents, and three sectors: households, firms, and the government. We build upon Trabandt and Uhlig (2011) and add features of EMDEs using Alba and McKnight (2022) and Papp and Takáts (2008). The present model is different from Trabandt and Uhlig (2011) in the following three ways: i) inclusion of heterogeneous agents with Ricardian and non-Ricardian households and firms, the difference being that non-Ricardian households and firms are exempt from paying taxes on labour and capital income;[14] ii) endogenizing tax evasion in labour and capital income tax by Ricardian households who hold varying affiliation to the norm of tax compliance in the society; iii) adding features to capture the ability of institutions to put a check on evasion in a minimalistic way, by adding the probability of tax auditing and penalty payments by individuals if caught evading taxes. The government is assumed to be passive, and it only collects taxes and makes transfer payments to the households. Figure 7 summarizes the model agents and their role in the economy.

[INSERT FIGURE 7]

[13] Calculated by Authors, using data from World Bank (2024b) and IMF's categorization of EMDEs and AEs. We have used data on the distribution of population between different income thresholds for the year 2021. Income thresholds are provided in the US dollars at 2017 prices.

[14] Trabandt and Uhlig (2011) extend their analysis to the case of heterogeneity in terms of human capital. However, they do not find a major difference in their results.

2.1. Households

The economy consists of a continuum of infinitely-lived households i in the interval [0,1]. Non-Ricardian households populate the interval $[0,\omega)$ while Ricardian households populate the interval $(\omega,1]$.[15] A share $(1-\gamma(.))$ of Ricardian households, derived endogenously, evade taxes. For a representative household i of type j, preferences are characterized by a Constant Frisch Elasticity (CFE) utility function,

$$u(c_t^j(i), n_t^j(i)) = \frac{1}{1-\eta}(c_t^j(i)^{1-\eta}(1-\kappa^j(1-\eta)n_t^j(i)^{1+\frac{1}{\psi^j}})^{\eta}-1) - \mu\phi^j(i), \tag{1}$$

where $\eta > 0$, $\eta \neq 1$, is the inverse of the intertemporal elasticity of consumption, ψ^j is the Frisch elasticity of labour supply, that differs for Ricardian ($j = r$) and non-Ricardian ($j = nr$) households, and $\kappa^j > 0$ is the weight of labour in the utility function, that differs across $j \in \{rh, re, nr\}$. $c_t^j(i)$ refers to consumption at time t, and $n_t^j(i)$ refers to labour supply at time t.[16] The type of household j can be rh for a Ricardian-honest taxpaying household, re for a Ricardian-evading household, and nr for a non-Ricardian household.[17] For depicting aggregates across Ricardian households, we replace j with r.[18] μ refers to the probability of getting caught in tax evasion, which is exogenous to the households. Each evading Ricardian household i derives a disutility $\phi^r(i)$ if caught post tax evasion. $\phi^r(i)$ represents an individual's affiliation to the norm of tax compliance in the society and this would vary across households. Countries where individuals have great trust in the government, or have lower perceptions towards corruption in the economy have higher norms of tax compliance and thus the disutility derived by individuals after being caught would be higher. As discussed in the introduction Section 1, the EMDEs have lower norms of tax compliance on an average than AEs and would thus have a lower mean of the disutility than the AEs.[19] $\phi^j(i)$ is 0 if j is nr, i.e., for the non-Ricardian households, as they do not indulge in tax evasion. $\phi^j(i)$ is distributed log-normally across the Ricardian households, i.e., $\phi^r(i)$ has a lognormal distribution across i, with mean μ_ϕ and variance σ_ϕ. Thus, $\mu\phi^j(i)$ represents the disutility of a household if it gets caught in tax evasion. Each j^{th} type of household maximizes its utility subject to the budget constraint, described later. For further analysis, we drop (i) used to denote the households for simplicity.

While the Ricardian and non-Ricardian households own the firms that they supply inputs to, they differ in four ways: i) firms owned by the Ricardian households produce goods using both

[15] Campbell and Mankiw (1989) introduce non-Ricardian or rule-of-thumb households that are constrained in that they do not have access to capital markets. In our model, Ricardian households are those who save and invest in capital and are eligible to pay labour and capital income taxes. Non-Ricardian households are not eligible for tax payments and are thus exempt from paying labour and capital income tax, and do not save and invest.

[16] The utility function is increasing and concave in consumption, and decreasing and concave in labour supply.

[17] We use honest households and tax evading households to refer to Ricardian-honest (rh) and Ricardian-evading (re) households respectively, later in the text.

[18] For instance, as mentioned in Section 2.2.2 below, n_t^r refers to the amount of labour hired by a Ricardian firm.

[19] Tsakumis et al. (2007) explore the relationship between Hofstede's cultural dimensions and tax evasion. McGee and George (2008) and Besley and Persson (2014) argue that perceptions of corruption in the economy discourage tax compliance. Jimenez and Iyer (2016) and Korgaonkar (2022) talk about trust in government, social and personal norms, and their relation to tax morale.

labour and capital as inputs, while firms owned by the non-Ricardian households use only labour as input; ii) the Ricardian households consume goods produced by both types of firms, whereas the non-Ricardian households only consume goods produced by the non-Ricardian firms.[20]; iii) the Ricardian firms save and invest in capital as well as government bonds, whereas the non-Ricardian households neither save nor invest; iv) the Ricardian households pay income taxes on the capital and labour income, while the non-Ricardian households do not pay any income taxes.

2.1.1. Ricardian Households

A Ricardian household decides whether to evade taxes. This decision is made in two stages. In the first stage, the household maximizes its utility in the case where it is honest, and in the case where it evades taxes. In the second stage, it decides whether to evade taxes.

If a Ricardian household pays taxes honestly, its utility is given by equation (1), replacing j with rh. The disutility of getting caught is 0 for an rh type household. The consumption basket is given as,

$$c_t^{rh} = [a_r^{\frac{1}{\epsilon_r}} (c_{r,t}^{rh})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1 - a_r)^{\frac{1}{\epsilon_r}} (c_{nr,t}^{rh})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{\epsilon_r}{\epsilon_r - 1}}, \tag{2}$$

where $c_{r,t}^{rh}$ and $c_{nr,t}^{rh}$ refer to the consumption of the Ricardian and non-Ricardian goods respectively, by an rh type household.[21] ϵ_r is the elasticity of substitution between the Ricardian and the non-Ricardian goods, and a_r is the weight given to the Ricardian goods in the consumption basket. The household decides how much of each type of good to consume given the budget constraint $p_t^r c_{r,t}^{rh} + p_t^{nr} c_{nr,t}^{rh} = M$, where p_t^r and p_t^{nr} denote prices of the goods produced by Ricardian and non-Ricardian sectors respectively. This yields demands for $c_{r,t}^{rh}$ and $c_{nr,t}^{rh}$ as,

$$c_{r,t}^{rh} = a_r (T_t^r)^{-\epsilon_r} c_t^{rh}, \tag{3}$$

$$c_{nr,t}^{rh} = (1 - a_r)(T_t^{nr})^{-\epsilon_r} c_t^{rh}, \tag{4}$$

where T_t^r and T_t^{nr} respectively refer to the terms of trade for the Ricardian and non-Ricardian sectors, defined as $T_t^r = \frac{p_t^r}{P_t^r}$ and $T_t^{nr} = \frac{p_t^{nr}}{P_t^r}$, with $P_t^r = [a_r (p_t^r)^{1-\epsilon_r} + (1 - a_r)(p_t^{nr})^{1-\epsilon_r}]^{\frac{1}{1-\epsilon_r}}$ being the CPI of the household's consumption basket given by equation (2) such that $P_t^r c_t^{rh} = p_t^r c_{r,t}^{rh} + p_t^{nr} c_{nr,t}^{rh}$.[22]

Further, honest taxpaying households make decisions regarding the level of consumption, c_t^{rh}, labour supply, n_t^{rh}, investment, x_t^{rh} and bond-holdings, b_t^{rh}. Equation (5) is the flow budget constraint at time t for an honest household. The left-hand side is the expenditure side, which consists of consumption, c_t^{rh} along with tax on consumption, τ_t^c, investment, x_t^{rh} and government bond-holdings,

[20] Papers such as Chai (2018), Clements and Si (2018) and Merella and Santabárbara (2016) show that as income increases, households demand high-quality products. For our calibrations, the consumption basket for Ricardian households has a higher share of Ricardian goods than non-Ricardian goods.

[21] Superscript j, as presented before, refers to household of type j, which may be rh, re, r or nr, while subscript k which may be r or nr, refers to consumption of good produced by the Ricardian or the non-Ricardian firm respectively.

[22] Details of the optimization decision for households are provided in Technical Appendix Section A.A.1.

b_t^{rh}. The right-hand side is the income side. It consists of labour income, $w_t^r n_t^{rh}$ net of taxes, τ_t^n, capital income, $d_t k_{t-1}^{rh}$ net of depreciation at the rate δ, and taxes, τ_t^k, returns on bond-holdings of the previous time period, $R_t^b b_{t-1}^{rh}$, lump-sum transfers from the government, s_t and firm profits, Π_t^{rh}.[23]

$$(1+\tau_t^c)c_t^{rh} + x_t^{rh} + b_t^{rh} = (1-\tau_t^n)w_t^r n_t^{rh} + (1-\tau_t^k)(d_t-\delta)k_{t-1}^{rh} + \delta k_{t-1}^{rh} + R_t^b b_{t-1}^{rh} + s_t + \Pi_t^{rh}. \quad (5)$$

Equation (6) represents the capital accumulation equation for honest households at period t, where k_t^{rh} is the level of capital, x_t^{rh} refers to investment and δ is the rate of depreciation of capital,

$$k_t^{rh} = (1-\delta)k_{t-1}^{rh} + x_t^{rh}. \quad (6)$$

An honest household maximizes the discounted sum of lifetime utility,

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

subject to equation (5) and equation (6). Aggregate government expenditure is denoted by g_t. Similar to Trabandt and Uhlig (2011), households take government expenditure as given and derive utility $\vartheta(g_t)$. The optimization for honest households gives us the Euler's equation (7), the labour supply equation (8), and the first order condition for investment (9),

$$R_{t+1}^b = \frac{1}{\beta} \frac{u'_{c_t^{rh}}}{(1+\tau_t^c)} \frac{(1+\tau_{t+1}^c)}{u'_{c_{t+1}^{rh}}}, \quad (7)$$

$$w_t^r = \frac{-u'_{n_t^{rh}}}{u'_{c_t^{rh}}} \frac{(1+\tau_t^c)}{(1-\tau_t^n)}, \quad (8)$$

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

$$R_{t+1}^b = 1 + (1-\tau_{t+1}^k)(d_{t+1}-\delta). \quad (9)$$

Similar to the above, we provide the analysis for a tax evading household. In the utility function given by equation (1), j is replaced by re for a Ricardian-evading household. For a tax evading household, the disutility $\mu\phi^{re}(i)$ comes into play, in case it gets caught with probability μ. The aggregate consumption basket of a tax evading household is given as,

$$c_t^{re} = [a_r^{\frac{1}{\epsilon_r}}(c_{r,t}^{re})^{\frac{\epsilon_r-1}{\epsilon_r}} + (1-a_r)^{\frac{1}{\epsilon_r}}(c_{nr,t}^{re})^{\frac{\epsilon_r-1}{\epsilon_r}}]^{\frac{\epsilon_r}{\epsilon_r-1}}, \quad (10)$$

[23] Since we have assumed the Ricardian firm to be perfectly competitive, it earns zero profits in equilibrium.

where $c^{re}_{r,t}$ and $c^{re}_{nr,t}$ refer to the consumption of the Ricardian and non-Ricardian goods respectively by an re type household. Given the budget constraint $p^r_t c^{re}_{r,t} + p^{nr}_t c^{re}_{nr,t} = M$, the demands for $c^{re}_{r,t}$ and $c^{re}_{nr,t}$ are given as,

$$c^{re}_{r,t} = a_r (T^r_t)^{-\epsilon_r} c^{re}_t, \tag{11}$$

$$c^{re}_{nr,t} = (1 - a_r)(T^{nr}_t)^{-\epsilon_r} c^{re}_t, \tag{12}$$

where T^r_t and T^{nr}_t are as explained above, such that $P^r_t c^{re}_t = p^r_t c^{re}_{r,t} + p^{nr}_t c^{re}_{nr,t}$.

The evading households make decisions regarding the level of aggregate consumption c^{re}_t, labour supply n^{re}_t, investment x^{re}_t and bond-holdings b^{re}_t. Equation (13) below is the flow budget constraint at time t for an honest household. The left-hand side is the expenditure side, which consists of consumption c^{re}_t along with a tax on consumption τ^c_t, investment x^{re}_t and government bond-holdings b^{re}_t. The right-hand side is the income side. It consists of labour income $w^r_t n^{re}_t$ net of taxes τ^n_t, capital income $d_t k^{re}_{t-1}$ net of taxes τ^k_t, returns on bond-holdings of the previous time period $R^b_t b^{re}_{t-1}$, lump-sum transfers from the government s_t and firm profits Π^{re}_t.[24]

$$(1+\tau^c_t)c^{re}_t + x^{re}_t + b^{re}_t = (1-\tau^n_t \mu(1+\pi)) w^r_t n^{re}_t + (1-\tau^k_t \mu(1+\pi))(d_t - \delta) k^{re}_{t-1} + \delta k^{re}_{t-1} + R^b_t b^{re}_{t-1} + s_t + \Pi^{re}_t. \tag{13}$$

The budget constraint for the tax evading household not only adjusts for taxes paid on labour and capital, i.e., τ^n_t and τ^k_t, but also for the probability of getting caught μ, and the penalty to be paid if the household gets caught π. In other words, with probability $1 - \mu$, the evading household does not get caught and retains the entire income earned, whereas, with probability μ, it gets caught and has to make a payment to the government at $(1 + \pi)$ times the tax rate. The capital accumulation equation for evading households at time period t is given by equation (14), where k^{re}_t is the level of capital and x^{re}_t refers to investment,

$$k^{re}_t = (1 - \delta) k^{re}_{t-1} + x^{re}_t. \tag{14}$$

An evading household maximizes the discounted sum of lifetime utility,

$$\max_{c^{re}_t, n^{re}_t, k^{re}_t, b^{re}_t} E_0 \sum_{t=0}^{\infty} \beta^t [u(c^{re}_t, n^{re}_t) + \vartheta(g_t)],$$

subject to equation (13) and equation (14). The optimization for households gives us the Euler's equation (15), the labour supply equation (16) and the first order condition for investment (17),

$$R^b_{t+1} = \frac{1}{\beta} \frac{u'_{c^{re}_t}}{(1 + \tau^c_t)} \frac{(1 + \tau^c_{t+1})}{u'_{c^{re}_{t+1}}}, \tag{15}$$

[24]Since we have assumed the Ricardian firm to be perfectly competitive, it earns zero profits in equilibrium.

$$w_t^r = \frac{-u'_{n_t^{re}}}{u'_{c_t^{re}}} \frac{(1+\tau_t^c)}{[1-\tau_t^n \mu(1+\pi)]}, \tag{16}$$

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

$$R_{t+1}^b = 1 + [1-\tau_{t+1}^k \mu(1+\pi)](d_{t+1}-\delta). \tag{17}$$

Tax Evasion Decision

The first order conditions provide the optimal consumption and labour supply, c_t^{rh} & n_t^{rh} if the household is honest, and c_t^{re} & n_t^{re} if the household evades taxes. If household i pays taxes honestly, it gets utility,

$$u(c_t^{rh}(i), n_t^{rh}(i)) = \frac{1}{1-\eta}(c_t^{rh}(i)^{1-\eta}(1-\kappa^{rh}(1-\eta)n_t^{rh}(i)^{1+\frac{1}{\psi^r}})^\eta - 1), \tag{18}$$

while if household i evades taxes, it gets utility,

$$u(c_t^{re}(i), n_t^{re}(i)) = \frac{1}{1-\eta}(c_t^{re}(i)^{1-\eta}(1-\kappa^{re}(1-\eta)n_t^{re}(i)^{1+\frac{1}{\psi^r}})^\eta - 1) - \mu\phi^r(i), \tag{19}$$

where, as expounded before, $\phi^r(i)$ has a lognormal distribution across Ricardian households with mean μ_ϕ and variance σ_ϕ. Each Ricardian household i has a level of disutility $\phi^r(i)$. However, an honest taxpaying household does not face the disutility of getting caught. Higher values of the disutility parameter $\phi^r(i)$ represent a social norm in favour of tax compliance in the economy. If the utility from paying taxes honestly, $u(c_t^{rh}(i), n_t^{rh}(i))$ exceeds the utility from tax evasion, $u(c_t^{re}(i), n_t^{re}(i))$, the household chooses to pay taxes honestly, and vice-versa. Let household k be indifferent between paying taxes honestly and evading taxes, such that $u(c_t^{rh}(k), n_t^{rh}(k)) = u(c_t^{re}(k), n_t^{re}(k))$. The value of the disutility parameter for this household is given as,

$$\hat{\phi}_t^r = \frac{u(c_t^{re}(k), n_t^{re}(k))_{partial} - u(c_t^{rh}(k), n_t^{rh}(k))}{\mu}, \tag{20}$$

where $u(c_t^{re}(k), n_t^{re}(k))_{partial} = \frac{1}{1-\eta}(c_t^{re}(k)^{1-\eta}(1-\kappa^{re}(1-\eta)n_t^{re}(k)^{1+\frac{1}{\psi^r}})^\eta - 1)$, i.e., the utility derived from evading taxes for household k, excluding the disutility of getting caught. Households i with $\phi^r(i) \geq \hat{\phi}_t^r$ choose to pay taxes honestly, whereas households i with $\phi^r(i) < \hat{\phi}_t^r$ choose to evade taxes. In other words, feeling subjective disutility beyond a certain level disincentivizes a household from evading taxes. Using $\hat{\phi}_t^r$, we can derive the share of tax evaders in an economy. Since $\phi^r(i)$ follows a lognormal distribution, the cdf $F(\hat{\phi}_t^r)$ provides the share of tax evaders in the economy. Thus, denoting the share of honest taxpayers by $\gamma(.)$, we have,

$$\gamma(\hat{\phi}_t^r) = 1 - F(\hat{\phi}_t^r). \tag{21}$$

2.1.2. Non-Ricardian Households

The non-Ricardian households only consume goods produced by the firms owned by them, and pay taxes only on consumption. A consumption tax cannot be evaded since it is an indirect tax and is included in commodity prices. Non-Ricardian households do not invest or save, do not receive capital income, and do not hold government bonds. The representative non-Ricardian household has utility given by equation (1) with j replaced by nr and $\phi^{nr}(i)$ as 0. The budget constraint is given as,

$$(1+\tau_t^c)T_t^{nr}c_{nr,t}^{nr} = T_t^{nr}w_t^{nr}n_t^{nr} + s_t + T_t^{nr}\Pi_t^{nr}, \tag{22}$$

where the left-hand side, i.e., the expenditure side consists of consumption expenditure $c_{nr,t}^{nr}$, inclusive of taxes τ_t^c, and the right-hand side, i.e., income side consists of wage income $w_t^{nr}n_t^{nr}$, lump-sum transfers from the government s_t and firm profits Π_t^{nr}.[25] The non-Ricardian households maximize 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 equation (22). Optimisation yields the labour supply equation (23) as,

$$w_t^{nr} = \frac{-u'_{n_t^{nr}}(1+\tau_t^c)}{u'_{c_{nr,t}^{nr}}}, \tag{23}$$

where $u'_{c_{nr}^{nr}}(c_{nr,t}^{nr}, n_t^{nr}) = \frac{1}{(c_{nr,t}^{nr})^{\eta}}[1-\kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi^{nr}}}]^{\eta}$,
$u'_{n^{nr}}(c_{nr,t}^{nr}, n_t^{nr}) = -\eta\kappa^{nr}(c_{nr,t}^{nr})^{1-\eta}(1+\frac{1}{\psi^{nr}})(n_t^{nr})^{\frac{1}{\psi^{nr}}}[1-\kappa^{nr}(1-\eta)(n_t^{nr})^{1+\frac{1}{\psi^{nr}}}]^{\eta-1}$.

2.2. Firms

The model has two types of perfectly competitive firms. The first type of firms are owned by the Ricardian households, both honest taxpaying and tax evading households. It is assumed that the labour and capital provided by the two types of Ricardian households are homogeneous. Superscript r refers to output produced by the Ricardian firms. The capital and labour supplied by the Ricardian households are aggregated as,

$$k_t = \int_0^{\gamma(.)} k_t^{rh}(i)di + \int_{\gamma(.)}^1 k_t^{re}(i)di, \tag{24}$$

and

$$n_t^r = \int_0^{\gamma(.)} n_t^{rh}(i)di + \int_{\gamma(.)}^1 n_t^{re}(i)di. \tag{25}$$

Since each rh household i, and each re household i, behaves the same way, we can rewrite equation (24) and equation (25) as $k_t = \gamma(.)k_t^{rh} + (1-\gamma(.))k_t^{re}$ and $n_t^r = \gamma(.)n_t^{rh} + (1-\gamma(.))n_t^{re}$ respectively.

[25] Since we have assumed the non-Ricardian firm to be perfectly competitive, it earns zero profits in equilibrium.

Production technology for the Ricardian sector is given as,

$$y_t^r = (A^r)^t k_{t-1}^{\theta} (n_t^r)^{1-\theta}, \tag{26}$$

where y_t^r is the output, A^r refers to the trend of total factor productivity, and θ is the share of capital used in production. We define the growth factor of the aggregate output as,

$$\zeta^r = (A^r)^{\frac{1}{1-\theta}}, \tag{27}$$

i.e. technological progress is labour-augmenting (Uzawa (1961)). Firms optimize in every period t. They decide on how much labour and capital to demand for each wage rate w_t^r and return on capital d_t, to maximize profits $\Pi_t^r = y_t^r - w_t^r n_t^r - d_t k_{t-1}$ subject to equation (26). Optimization results in the demands for capital and labour as,

$$k_{t-1} = \theta \frac{y_t^r}{d_t}, \tag{28}$$

$$n_t^r = (1-\theta) \frac{y_t^r}{w_t^r}. \tag{29}$$

The second type of firms are owned by the non-Ricardian households, and they use only labour as the input. Superscript nr refers to output produced by non-Ricardian firms. Production technology is given as,

$$y_t^{nr} = (A^{nr})^t n_t^{nr}, \tag{30}$$

where y_t^{nr} is the output of a non-Ricardian firm and A^{nr} is the trend of total factor productivity. We assume that $A^{nr} < A^r$, i.e., the non-Ricardian sector has a lower level of productivity than the Ricardian sector.[26] The firms decide how much labour to demand for each wage rate w_t^{nr} to maximize profits $\Pi_t^{nr} = y_t^{nr} - w_t^{nr} n_t^{nr}$ subject to equation (30). Optimisation yields the labour demand as,

$$n_t^{nr} = \frac{y_t^{nr}}{w_t^{nr}}. \tag{31}$$

Aggregate output is defined as $y_t = (1-\omega) y_t^r + \omega T_t^{nr} y_t^{nr}$, in terms of the price of consumption bundle of the Ricardian households.

2.3. Goods-Market Equilibrium

Total consumption for the economy, c_t, is given as,

$$\begin{aligned} c_t &= (1-\omega)[\gamma(.) c_t^{rh} + (1-\gamma(.)) c_t^{re}] + \omega T_t^{nr} c_{nr,t}^{nr} \\ &= (1-\omega)[\gamma(.)(T_t^r c_{r,t}^{rh} + T_t^{nr} c_{nr,t}^{rh}) + (1-\gamma(.))(T_t^r c_{r,t}^{re} + T_t^{nr} c_{nr,t}^{re})] + \omega T_t^{nr} c_{nr,t}^{nr}. \end{aligned} \tag{32}$$

[26]See Amin and Okou (2020).

Rearranging the terms, we get,

$$\begin{aligned}c_t &= (1-\omega)T_t^r(\gamma(.)c_{r,t}^{rh} + (1-\gamma(.))c_{r,t}^{re}) + T_t^{nr}((1-\omega)(\gamma(.)c_{nr,t}^{rh} + (1-\gamma(.))c_{nr,t}^{re}) + \omega c_{nr,t}^{nr})\\ &= T_t^r c_{r,t} + T_t^{nr} c_{nr,t},\end{aligned}$$

i.e., the total consumption in the economy is a combination of the consumption of goods produced by the Ricardian firms, $c_{r,t}$, which includes consumption by the honest taxpaying households $c_{r,t}^{rh}$, and the consumption by the tax evading households $c_{r,t}^{re}$,

$$c_{r,t} = (1-\omega)(\gamma(.)c_{r,t}^{rh} + (1-\gamma(.))c_{r,t}^{re}), \tag{33}$$

and the consumption of goods produced by the non-Ricardian firms, $c_{nr,t}$, which includes the consumption by the honest taxpaying households $c_{nr,t}^{rh}$, by the tax evading households $c_{nr,t}^{re}$ and by the non-Ricardian households $c_{nr,t}^{nr}$,

$$c_{nr,t} = (1-\omega)(\gamma(.)c_{nr,t}^{rh} + (1-\gamma(.))c_{nr,t}^{re}) + \omega c_{nr,t}^{nr}. \tag{34}$$

Further, total output y_t is given as,

$$y_t = (1-\omega)y_t^r + \omega T_t^{nr} y_t^{nr}, \tag{35}$$

where $y_t^r = w_t^r n_t^r + d_t k_{t-1}^r$ and $y_t^{nr} = w_t^{nr} n_t^{nr}$. Defining $x_t = \gamma x_t^{rh} + (1-\gamma)x_t^{re}$, the goods market equilibrium condition reduces to,[27]

$$c_t + (1-\omega)x_t + g_t = y_t. \tag{36}$$

2.4. Government

The government budget constraint is given as,

$$g_t + s_t + (1-\omega)R_t^b b_{t-1} = (1-\omega)b_t + T_t. \tag{37}$$

The government earns tax revenues T_t and borrows from the market using government bonds b_t held by only the Ricardian households with share $(1-\omega)$. The expenditure side consists of general government expenditure g_t, lump-sum transfers to households s_t, and returns on government bonds held in the previous period $R_t^b b_{t-1}$. Equation (38) below provides the components of T_t, i.e. the tax revenues of the government. Taxes on consumption are paid by both the types of households, while taxes on labour and capital income are only paid by the Ricardian households with share $(1-\omega)$. As stated previously, a proportion $\gamma(.)$ of the Ricardian households pays taxes honestly, while $(1-\gamma(.))$ proportion evades taxes. With probability μ, the evaders get caught and have to

[27]The detailed derivation is provided in Technical Appendix Section A.A.2.

pay a penalty at π times the tax rate.

$$
\begin{aligned}
T_t =& \tau_t^c\{\omega T_t^{nr} c_{nr,t}^{nr} + (1-\omega)[\gamma(.)c_t^{rh} + (1-\gamma(.))c_t^{re}]\} \\
&+ (1-\omega)\{\tau_t^n[\gamma(.)w_t^r n_t^{rh} + (1-\gamma(.))\mu(1+\pi)w_t^r n_t^{re}] \\
&+ \tau_t^k[\gamma(.)(d_t-\delta)k_{t-1}^{rh} + (1-\gamma(.))\mu(1+\pi)(d_t-\delta)k_{t-1}^{re}]\},
\end{aligned} \tag{38}
$$

where $c_t^{rh} = T_t^r c_{r,t}^{rh} + T_t^{nr} c_{nr,t}^{rh}$, $c_t^{re} = T_t^r c_{r,t}^{re} + T_t^{nr} c_{nr,t}^{re}$ are the consumption by Ricardian (honest and evading respectively) households that include the consumption of goods produced by both the sectors, and $c_t^{nr} = T_t^{nr} c_{nr,t}^{nr}$ is the consumption by non-Ricardian agents of their own goods.

Total welfare at the steady state is calculated as the sum of lifetime utility for the Ricardian-honest, Ricardian-evading, and the non-Ricardian households. Welfare at time t is given as,

$$
\begin{aligned}
W_t &= \int_0^{\omega} u(c_{nr,t}^{nr}, n_t^{nr}) + \int_{\omega}^{1}[\int_0^{\gamma(.)} u(c_t^{rh}, n_t^{rh}) + \int_{\gamma(.)}^{1} u(c_t^{re}, n_t^{re})] \\
&= \omega u(c_{nr,t}^{nr}, n_t^{nr}) + (1-\omega)[\gamma(.)u(c_t^{rh}, n_t^{rh}) + (1-\gamma(.))u(c_t^{re}, n_t^{re})].
\end{aligned} \tag{39}
$$

Thus, we get lifetime utility as the discounted sum of W_t over time,

$$
W = \sum_0^{\infty} \beta^t\{(1-\omega)[\gamma(.)u(c_t^{rh}, n_t^{rh}) + (1-\gamma(.))u(c_t^{re}, n_t^{re})] + \omega u(c_{nr,t}^{nr}, n_t^{nr})\}. \tag{40}
$$

2.5. Statutory and Effective Tax Rates

In this paper, we make a distinction between statutory and effective tax rates. Statutory tax rates are the tax rates set by the government, represented by τ^c, τ^n and τ^k, for the tax rate on consumption, labour income and capital income, respectively, in our model. On the other hand, the effective tax rates are based on the tax revenues received by the government as a share of the total taxable income, taking into account tax exemptions and tax evasion. Following Balajee et al. (2024), we define the 'Average Effective Tax Rate' as the aggregate tax incidence on a factor of production (i.e. capital or labour in our model) divided by the pre-tax income for that factor of production (i.e. capital or wage income of the Ricardian households, that is taxable). For the consumption tax, τ^c, the statutory tax rate equals the effective tax rate because there are neither tax exemptions nor tax evasion in consumption. In our model, the effective tax rate on labour income can be calculated as,

$$
\tilde{\tau_t^n} = \tau_t^n\{\frac{\gamma(.)w_t^r n_t^{rh} + (1-\gamma(.))\mu(1+\pi)w_t^r n_t^{re}}{\gamma(.)w_t^r n_t^{rh} + (1-\gamma(.))w_t^r n_t^{re}}\},
$$

and for capital income it would be,

$$
\tilde{\tau_t^k} = \tau_t^k\{\frac{\gamma(.)(d_t-\delta)k_{t-1}^{rh} + (1-\gamma(.))\mu(1+\pi)(d_t-\delta)k_{t-1}^{re}}{\gamma(.)(d_t-\delta)k_{t-1}^{rh} + (1-\gamma(.))(d_t-\delta)k_{t-1}^{re}}\}.
$$

Thus, the effective tax rates are lower than the statutory tax rates in the presence of tax evasion.[28] In the Laffer curves that follow, we derive the optimal statutory tax rates.

2.6. Assumptions

We assume, as in Trabandt and Uhlig (2011), that along the balanced growth path, government spending and government debt grow at the same rate, i.e., the growth factor of type r output. For a variable x_t, $\overline{x}$ represents its balanced growth path. The growth paths are given as,

$$g_t = (\zeta^r)^t \overline{g}, \tag{41}$$

$$b_{t-1} = (\zeta^r)^t \overline{b}. \tag{42}$$

Thus, the government budget constraint given by equation (37) can be rewritten as,

$$s_t = (1-\omega)(\zeta^r)^t \overline{b}(\zeta^r - R^b_t) + T_t - (\zeta^r)^t \overline{g}. \tag{43}$$

In other words, in response to a change in tax rates (and thus tax revenues T_t), lump-sum transfers s_t adjust to balance the budget constraint, while government expenditure g_t and bond holdings b_t stay along the balanced growth path.

2.7. Balanced Growth Paths

We provide the balanced growth path (BGP) equations for the capital to output ratio for the Ricardian-honest households, $\frac{k^{rh}_{t-1}}{y^r_t}$ and for the Ricardian-evading households, $\frac{k^{re}_{t-1}}{y^r_t}$, the consumption to output ratio for the Ricardian-honest households, $\frac{c^{rh}_t}{y^r_t}$, the Ricardian-evading households, $\frac{c^{re}_t}{y^r_t}$ and the non-Ricardian households, $\frac{c^{nr}_t}{y^{nr}_t}$, and the labour supply of the Ricardian-honest households, n^{rh}_t, the Ricardian-evading households, n^{re}_t and the non-Ricardian households, n^{nr}_t.[29]

First, we derive the capital to output ratio for honest households. Substituting for d_t from equation (28) in equation (9), we have,

$$R^b_{t,t+1} - 1 = (1-\tau^k_{t+1})(\theta \frac{y^r_{t+1}}{k^{rh}_t} - \delta). \tag{44}$$

With some simple algebraic manipulation, we obtain the capital-to-output ratio for honest households along the balanced growth path as,

$$\overline{k^{rh}/y^r} = [\frac{\overline{R^b} - 1}{\theta(1-\overline{\tau^k})} + \frac{\delta}{\theta}]^{-1}, \tag{45}$$

[28] This is true when $\mu(1+\pi) < 1$. This is consistent with what we see in Proposition 1 in the results Section 4.
[29] Details of the derivation are provided in Technical Appendix Section A.A.3.

where $\overline{R^b} = \frac{(\zeta^r)^\eta}{\beta}$ gives the balanced-growth return on bonds. The capital-to-output ratio is independent of tax on labour and consumption and decreases with an increase in tax on capital. Further, it falls as returns on bonds rise. The BGP labour supply for an honest household can be derived using the Euler's equation (8) as follows,

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

Substituting for w_t^r from equation (29) and with some algebraic manipulation, we get,

$$\frac{c_t^{rh}}{y_t^r} = [\frac{(1-\tau_t^n)(1-\theta)}{(1+\tau_t^c)(1+\frac{1}{\psi^r})}][\frac{1-\kappa^{rh}(1-\eta)(n_t^{rh})^{1+\frac{1}{\psi^r}}}{\eta\kappa^{rh}(n_t^{rh})^{1+\frac{1}{\psi^r}}}]. \tag{46}$$

Separating n_t^{rh} we get,

$$n_t^{rh} = [\kappa^{rh}(\eta\alpha_t^{rh}c_t^{rh}/y_t^r - \eta + 1)]^{\frac{-\psi^r}{1+\psi^r}}, \tag{47}$$

where $\alpha_t^{rh} = \frac{(1+\tau_t^c)(1+\frac{1}{\psi^r})}{(1-\tau_t^n)(1-\theta)}$.

Thus, labour supply along the balanced growth path is given as,

$$\overline{n^{rh}} = [\kappa^{rh}(\eta\overline{\alpha^{rh}c^{rh}/y^r} - \eta + 1)]^{\frac{-\psi^r}{1+\psi^r}}, \tag{48}$$

where $\overline{\alpha^{rh}} = \frac{(1+\overline{\tau^c})(1+\frac{1}{\psi^r})}{(1-\overline{\tau^n})(1-\theta)}$.

Further, we derive the consumption-to-output ratio for an honest household. We use equation (5), equation (6), substitute for k_t^{rh} by $\zeta^r k_{t-1}^{rh}$, b_{t-1}^{rh} by $(\zeta^r)^t\overline{b}$, and use equations (28) and (29), to get the following equation.[30]

$$(1+\tau_t^c)c_t^{rh}+(\zeta^r-1+\delta)k_{t-1}^{rh}+(\zeta^r)^{t+1}\overline{b} = (1-\tau_t^n)(1-\theta)y_t^r+(1-\tau_t^k)(\theta y_t^r-\delta k_{t-1}^{rh})+\delta k_{t-1}^{rh}+R_t^b(\zeta^r)^t\overline{b}+s_t.$$

Dividing throughout by y_t^r we get,

$$(1+\tau_t^c)\frac{c_t^{rh}}{y_t^r} = 1-(\zeta^r-1+\delta)\frac{k_{t-1}^{rh}}{y_t^r}+(R_t^b-\zeta^r)(\zeta^r)^t\overline{b}/y_t^r+s_t/y_t^r-[\tau_t^n(1-\theta)+\tau_t^k(\theta-\delta k_{t-1}^{rh}/y_t^r)]. \tag{49}$$

Thus along the balanced growth path,

$$\overline{c^{rh}/y^r} = \frac{1}{(1+\overline{\tau^c})}\{1-(\zeta^r-1+\delta)\overline{k^{rh}/y^r}+\overline{s/y}\overline{y}/\overline{y^r}+(\overline{R^b}-\zeta^r)\overline{b/y}\overline{y}/\overline{y^r}-[\overline{\tau^n}(1-\theta)+\overline{\tau^k}(\theta-\delta\overline{k^{rh}/y^r})]\}. \tag{50}$$

[30] We assume the balanced growth path for b_{t-1}^{rh} to be the same as for aggregate bond holdings b_{t-1} as given in Section 2.2.6.

Similar to an honest household, we derive the balanced growth path equations for a tax evading household. Substituting for d_t from equation (28) in equation (17), we have,

$$R^b_{t,t+1} - 1 = [1 - \tau^k_{t+1}\mu(1+\pi)](\theta\frac{y^r_{t+1}}{k^{re}_t} - \delta). \tag{51}$$

Thus, we obtain the capital-to-output ratio for evading households as,

$$\overline{k^{re}/y^r} = [\frac{\overline{R^b} - 1}{\theta[1 - \overline{\tau^k}\mu(1+\pi)]} + \frac{\delta}{\theta}]^{-1}. \tag{52}$$

The capital-to-output ratio falls as the probability of getting caught μ and the penalty on getting caught π rise.[31] We derive the BGP labour supply for a tax evading household using the Euler's equation (16) as follows,

$$\frac{\frac{1}{(c^{re}_t)^\eta}[1 - \kappa^{re}(1-\eta)(n^{re}_t)^{1+\frac{1}{\psi^r}}]^\eta}{-\eta\kappa^{re}(c^{re}_t)^{1-\eta}(1+\frac{1}{\psi^r})(n^{re}_t)^{\frac{1}{\psi^r}}[1 - \kappa^{re}(1-\eta)(n^{re}_t)^{1+\frac{1}{\psi^r}}]^{\eta-1}} = \frac{-(1+\tau^c_t)}{(1-\tau^n_t\mu(1+\pi))w^r_t}.$$

Substituting for w^r_t from equation (29) and with some algebraic manipulation, we get,

$$\frac{c^{re}_t}{y^r_t} = [\frac{(1-\tau^n_t\mu(1+\pi))(1-\theta)}{(1+\tau^c_t)(1+\frac{1}{\psi^r})}][\frac{1 - \kappa^{re}(1-\eta)(n^{re}_t)^{1+\frac{1}{\psi^r}}}{\eta\kappa^{re}(n^{re}_t)^{1+\frac{1}{\psi^r}}}]. \tag{53}$$

Separating n^{re}_t we get,

$$n^{re}_t = [\kappa^{re}(\eta\alpha^{re}_t c^{re}_t/y^r_t - \eta + 1)]^{\frac{-\psi^r}{1+\psi^r}}, \tag{54}$$

where $\alpha^{re}_t = \frac{(1+\tau^c_t)(1+\frac{1}{\psi^r})}{(1-\tau^n_t\mu(1+\pi))(1-\theta)}$.
Thus labour supply along the balanced growth path is given as,

$$\overline{n^{re}} = [\kappa^{re}(\eta\overline{\alpha^{re}}\,\overline{c^{re}/y^r} - \eta + 1)]^{\frac{-\psi^r}{1+\psi^r}}, \tag{55}$$

where $\overline{\alpha^{re}} = \frac{(1+\overline{\tau^c})(1+\frac{1}{\psi^r})}{(1-\overline{\tau^n}\mu(1+\pi))(1-\theta)}$.
To derive the consumption to output ratio, we use equation (13), equation (14), substitute for k^{re}_t by $\zeta^r k^{re}_{t-1}$, b^{re}_{t-1} by $(\zeta^r)^t\overline{b}$, and use equations (28) and (29), to get the below equation.[32]

$$\begin{aligned}(1+\tau^c_t)c^{re}_t + (\zeta^r - 1 + \delta)k^{re}_{t-1} + (\zeta^r)^{t+1}\overline{b} =& [1 - \tau^n_t\mu(1+\pi)](1-\theta)y^r_t + [1 - \tau^k_t\mu(1+\pi)](\theta y^r_t - \delta k^{re}_{t-1}) \\ &+ \delta k^{re}_{t-1} + R^b_t(\zeta^r)^t\overline{b} + s_t.\end{aligned}$$

[31] For $\overline{k^{re}/y^r} > 0$, we need $\overline{\tau^k} < \frac{1}{\mu(1+\pi)}$.

[32] We assume the balanced growth path for b^{re}_{t-1} to be the same as for aggregate bond holdings b_{t-1} as given in Section 2.2.6.

Dividing throughout by y_t^r we get,

$$(1+\tau_t^c)\frac{c_t^{re}}{y_t^r} = 1-(\zeta^r-1+\delta)\frac{k_{t-1}^{re}}{y_t^r}+(R_t^b-\zeta^r)(\zeta^r)^t\overline{b}/y_t^r+s_t/y_t^r-\mu(1+\pi)[\tau_t^n(1-\theta)+\tau_t^k(\theta-\delta k_{t-1}^{re}/y_t^r)]. \tag{56}$$

Thus along the balanced growth path,

$$\begin{aligned}\overline{c^{re}/y^r} = \frac{1}{(1+\overline{\tau^c})}\{1-(\zeta^r-1+\delta)\overline{k^{re}/y^r}+\overline{s/y}\overline{y}/\overline{y^r}+(\overline{R^b}-\zeta^r)\overline{b/y}\overline{y}/\overline{y^r} \\ -\mu(1+\pi)[\overline{\tau^n}(1-\theta)+\overline{\tau^k}(\theta-\delta\overline{k^{re}/y^r})]\}.\end{aligned} \tag{57}$$

We observe that the consumption-to-output ratio falls with a rise in all tax rates.

To derive the labour supply by non-Ricardian households, we use equation (23),

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

Thus, labour supply along the balanced growth path is given as,

$$\overline{n^{nr}} = [\kappa^{nr}(\eta\overline{\alpha^{nr}}\overline{c^{nr}/y^{nr}}-\eta+1)]^{\frac{-\psi^{nr}}{1+\psi^{nr}}}, \tag{58}$$

where $\overline{\alpha^{nr}} = (1+\overline{\tau^c})(1+\frac{1}{\psi^{nr}})$.
Further, using equation (22) and equation (31), we get,

$$(1+\tau_t^c)T_t^{nr}c_{nr,t}^{nr} = T_t^{nr}y_t^{nr}+s_t.$$

Dividing through by $y_t^{nr}T_t^{nr}$, we get the consumption-to-output ratio for a non-Ricardian household along the balanced growth path,

$$\overline{c_{nr}^{nr}/y^{nr}} = \frac{1}{(1+\overline{\tau^c})}\{1+\overline{s/y}\overline{y}/\overline{y^{nr}}\frac{1}{\overline{T^{nr}}}\}. \tag{59}$$

Along the balanced growth path, welfare would be,

$$\begin{aligned}\overline{W} &= \sum_0^{\infty}\beta^t\{(1-\omega)[\gamma(.)u(\overline{c^{rh}},\overline{n^{rh}})+(1-\gamma(.))u(\overline{c^{re}},\overline{n^{re}})]+\omega u(\overline{c_{nr}^{nr}},\overline{n^{nr}})\} \\ &= \frac{1}{1-\beta}\{(1-\omega)[\gamma(.)u(\overline{c^{rh}},\overline{n^{rh}})+(1-\gamma(.))u(\overline{c^{re}},\overline{n^{re}})]+\omega u(\overline{c_{nr}^{nr}},\overline{n^{nr}})\}.\end{aligned} \tag{60}$$

2.8. Laffer Curve

From the tax revenue equation (38), we have,

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

where $c_t^{rh} = T_t^r c_{r,t}^{rh} + T_t^{nr} c_{nr,t}^{rh}$, $c_t^{re} = T_t^r c_{r,t}^{re} + T_t^{nr} c_{nr,t}^{re}$ and $c_t^{nr} = T_t^{nr} c_{nr,t}^{nr}$.
Dividing throughout by y_t^r and using the firm optimality conditions provides the BGP equation for the Laffer curve,[33]

$$\begin{aligned} L = \overline{T/y} =& \overline{\tau^c}\{\omega\overline{T^{nr}}\,\overline{c_{nr}^{nr}/y^{nr}}.\overline{y^{nr}/n^{nr}}.\overline{n^{nr}} + (1-\omega)[\gamma(.)\overline{c^{rh}/y^r}.\overline{y^r/n^r}.\overline{n^r} + (1-\gamma(.))\overline{c^{re}/y^r}.\overline{y^r/n^r}.\overline{n^r}]\} \\ &+ (1-\omega)\{\overline{\tau^n}[\gamma(.)(1-\theta)\overline{y^r}/\overline{y} + (1-\gamma(.))\mu(1+\pi)(1-\theta)\overline{y^r}/\overline{y}] \\ &+ \tau^k[\gamma(.)(\theta - \delta\overline{k^{rh}/y^r})\overline{y^r}/\overline{y} + (1-\gamma(.))\mu(1+\pi)(\theta-\delta\overline{k^{re}/y^r})\overline{y^r}/\overline{y}]\}. \end{aligned} \tag{61}$$

Lemma 1. *For any tax rate on capital income, τ^k and labour income, τ^n, a Ricardian household i with disutility parameter, $\phi^r(i) \geq 0$, makes a decision to evade based on the critical value of the disutility parameter, $\hat{\phi}_t^r$, where $\hat{\phi}_t^r \in (-\infty, \infty)$ as described in equation (20). Further, assuming a lognormal distribution on $\phi^r(i)$, the proportion of honest Ricardian households in the economy, $\gamma(\hat{\phi}_t^r)$ where $0 \leq \gamma(\hat{\phi}_t^r) \leq 1$ will be as follows using equation (21). When $\hat{\phi}_t^r \leq 0$ all the Ricardian households choose to be honest and the share of honest households $\gamma(\hat{\phi}_t^r) = 1$. When $0 < \hat{\phi}_t^r < \infty$, the Ricardian households with $\phi^r(i) \geq \hat{\phi}_t^r$ choose to be honest and those with $\phi^r(i) < \hat{\phi}_t^r$ choose to evade, such that $\gamma(\hat{\phi}_t^r) \in (0,1)$. When the critical value of the disutility parameter is sufficiently large i.e. $\hat{\phi}_t^r \to \infty$ all households decide to evade so that the proportion of honest households $\gamma(\hat{\phi}_t^r) = 0$.*

Proof. We assume that $\phi^r(i)$ follows the lognormal distribution, with a non-negative support.

1. When $\hat{\phi}_t^r \leq 0$, the utility from being honest is higher than that from evasion. As $\phi^r(i)$ is non-negative, $\phi^r(i) \geq \hat{\phi}_t^r$ would always hold. Thus, all the households choose to be honest. Alternatively, $F(\hat{\phi}_t^r) = 0$ and following equation (21) we get $\gamma(\hat{\phi}_t^r) = 1 - F(\hat{\phi}_t^r) = 1$. Thus, the proportion of honest Ricardian households in the economy is 1, i.e., all the Ricardian households choose to be honest.

2. When $0 < \hat{\phi}_t^r < \infty$ we have a more interesting case. For all households i with $\phi^r(i) < \hat{\phi}_t^r$, we have $u(c_t^{rh}(i), n_t^{rh}(i)) < u(c_t^{re}(i), n_t^{re}(i))$. These households choose to evade taxes. On the other hand, for all households i with $\phi^r(i) \geq \hat{\phi}_t^r$, we obtain $u(c_t^{rh}(i), n_t^{rh}(i)) \geq u(c_t^{re}(i), n_t^{re}(i))$. These households choose to pay taxes honestly. $F(\hat{\phi}_t^r)$, i.e. the mass of households that evade taxes, takes some positive value in the interval $(0,1)$. Thus, $\gamma(\hat{\phi}_t^r) = 1 - F(\hat{\phi}_t^r) \in (0,1)$ provides the mass of households that pay taxes honestly.

[33] Details of the derivation are provided in Technical Appendix Section A.A.4.

3. When $\hat{\phi}_t^r$ is sufficiently large, such that $\phi^r(i) < \hat{\phi}_t^r \; \forall i$, all Ricardian households decide to evade taxes. Thus, $F(\hat{\phi}_t^r) = 1$, and $\gamma(\hat{\phi}_t^r) = 1 - F(\hat{\phi}_t^r) = 0$, i.e., the proportion of honest Ricardian households in the economy is 0.

□

3. Calibrations

Tables 1 and 2 summarise the calibrations for the variables and the parameters used in the model respectively. We calibrate the model using a set of EMDEs depending on the similarity of economic indicators such as the tax-to-GDP ratio and statutory tax rates. The initial values for variables provided in Table 1 are calculated by taking averages over the time period 2005-2019, for India, Indonesia, the Philippines, Sri Lanka, and .[34]

[INSERT TABLE 1 AND TABLE 2]

We use World Bank (2024d) to collect the data for debt to GDP ratio, $\overline{b/y}$, government consumption to GDP ratio, $\overline{g/y}$, investment as a share of income, $\overline{x^{rh}/y^r}$ and $\overline{x^{re}/y^r}$, and consumption as share of income, $\overline{c^{rh}/y^r}$, $\overline{c^{re}/y^r}$, and $\overline{c^{nr}/y^{nr}}$. The value for government transfers to GDP ratio, $\overline{s/y}$ is estimated using data from World Bank (2024d) and IMF (2024). Data for capital stock as a share of income, $\overline{k^{rh}/y^r}$ and $\overline{k^{re}/y^r}$, is collected from Feenstra et al. (2015). The steady state ratio of capital to income and investment to income is assumed to be the same for the honest and evading households. Similarly, the steady state value for the consumption to income ratio is assumed to be the same for honest, evading, and non-Ricardian households.[35] Data on labour hours, $\overline{n^{rh}}$ and $\overline{n^{re}}$, is collected from Feenstra et al. (2015). The value for labour supply by the non-Ricardian households, $\overline{n^{nr}}$, is kept higher, as the literature shows for EMDEs (see Raveendran and Vanek (2020), Bank (2020), Yu (2004), GOV (2023)). The return on government bonds, $\overline{R^b}$, is calculated as the residual from the balanced growth path equation for the capital stock to income ratio, equation 45, giving a value of 1.08.[36] We collect data on statutory tax rates on capital income, τ^k, labour income, τ^n, and consumption, τ^c, from World Bank (2024c). Since our model makes the distinction between statutory tax rates set by the government and effective tax rates, we use statutory tax rates for our calibration.[37]

We take the value of η at 1.2, which gives the value of elasticity of intertemporal substitution (EIS) for our model as 0.84.[38] For the Frisch elasticity of labour supply, ψ^r, we take the value

[34] Details of the calibrations are provided in Data Appendix Section B.B.2. We use MATLAB 2023b to conduct simulations based on the model and obtain our results.

[35] We conduct a sensitivity test by taking different initial values but the model does not show any significant changes.

[36] This is calculated as $\overline{R^b} = 1 + \frac{(1-\overline{\tau^k})}{(\theta/\overline{k^{rh}/y^r}-\delta)}$ where $\overline{\tau^k}, \overline{k^{rh}/y^r}, \delta$ and θ are as given in Tables 1 and 2.

[37] Trabandt and Uhlig (2011) and Alba and McKnight (2022) use effective tax rates.

[38] Thimme (2017) shows that the elasticity of intertemporal substitution (EIS), $1/\eta$, varies widely in the literature. Trabandt and Uhlig (2011) take the values 1 and 2.

of 6 for the Ricardian households.[39] We take a higher value of elasticity, ψ^{nr}, at 8, for the non-Ricardian households (see Aemkulwat (2014)). The values of the weight of labour, κ^{rh}, κ^{re} and κ^{nr}, are set such that they are consistent with labour supply estimates given in Table 1, following the methodology of Trabandt and Uhlig (2011).[40]

Alba and McKnight (2022) have calculated values for the share of formal goods in the consumption basket of households, a_r, in the range of 0.34 and 0.62. We take the value 0.6 as the share of consumption of non-Ricardian goods, since the share of Ricardian households, ω, has been proxied by the share of informal sector employment in our model. For the elasticity of substitution between formal and informal goods, ϵ_r, Alba and McKnight (2022) take the value 2.5. We take a low value of the elasticity of substitution by Ricardian households, between Ricardian and non-Ricardian goods, at 1. This is because Chai (2018) states that the high-income consumers have a preference for better quality products. Ricardian households will prefer to purchase products that are of high-quality, produced using labour and capital inputs, i.e., produced in the Ricardian sector. The rate of depreciation, δ is calculated as the residual from the capital accumulation equation for the Ricardian honest households along the balanced growth path, equation 6, given the initial values of capital stock to GDP ratio, investment to GDP ratio, and growth rate for the Ricardian sector.[41] We get a value of 0.03 for δ. The growth rate for the Ricardian sector is based on the estimates of GDP from Feenstra et al. (2015), and we get a value of 1.057, or 5.7 percent growth. For the non-Ricardian sector, we use estimates of the informal sector output as a share of GDP provided by Elgin et al. (2021a). We get a value of 1.04, or 4 percent for the same. Following the average from Reserve Bank of India (2024), we take a value of 0.5 for θ.[42] We estimate the value of A^r, the total factor productivity for the Ricardian sector, from equation 27, using the values of ζ^r and θ, and get a value of 1.02.[43] We take the value of A^{nr} as 0.25.[44]

We take the probability of getting caught at 2 percent, following Tandon and Rao (2017).[45] The penalty on getting caught, π, is taken to be 3 times the amount of tax evasion, following Papp and Takáts (2008), Samuel and Vu (2021) and PWC (2024).[46] The share of non-Ricardian households, ω, is proxied by the share of informal sector employment. We have taken it to be 75 percent, which

[39] Peterman (2016) shows that values in macroeconomic models vary from 2 to 4.

[40] Using equations 48, 55 and 58, and the initial values as given in Tables 1 and 2, we take $\kappa^{rh} = \frac{(\overline{n^{rh}})^{\frac{-(1+\psi^r)}{\psi^r}}}{(\eta\overline{\alpha^{rh}c^{rh}/y^r} - \eta + 1)}$, $\kappa^{re} = \frac{(\overline{n^{re}})^{\frac{-(1+\psi^r)}{\psi^r}}}{(\eta\overline{\alpha^{re}c^{re}/y^r} - \eta + 1)}$ and $\kappa^{nr} = \frac{(\overline{n^{nr}})^{\frac{-(1+\psi^{nr})}{\psi^{nr}}}}{(\eta\overline{\alpha^{nr}c^{nr}/y^{nr}} - \eta + 1)}$.

[41] We take $\delta = \frac{\overline{x^{rh}/y^r}}{\overline{k^{rh}/y^r}} - \zeta^r + 1$ where $\overline{x^{rh}/y^r}, \overline{k^{rh}/y^r}$ and ζ^r are as given in Tables 1 and 2.

[42] Estimates on the share of capital in production vary across countries (see Duma (2007), Başeğmez (2021), Le et al. (2019)).

[43] Using equation 27, we calculate this as $A^r = (\zeta^r)^{(1-\theta)}$, where ζ^r and θ are as given in Table 2.

[44] Amin and Okou (2020) reports that the labour productivity of informal firms is on an average one-fourth that of formal firms.

[45] Tandon and Rao (2017) says that the Income Tax Department in India audits 2 percent of taxpayers. Minh (2013) says that in 2012, 1.6 percent of the total corporations were audited in Vietnam. Papp and Takáts (2008) achieve a value of 3.3 percent as the probability of auditing and getting caught in their model, for the Russian economy.

[46] For India, the penalty on tax evasion is 3 times the amount of tax evaded. For Vietnam, it is 1-3 times the amount of tax evaded. Papp and Takáts (2008) take a value of 3 for Russia. Further, some countries such as Indonesia and the Philippines charge a lump-sum penalty on late payment or failure to pay taxes.

is the average across the countries listed above.[47] The disutility parameter, ϕ^r, follows a lognormal distribution. The mean, μ_ϕ, is 0, following Papp and Takáts (2008). They assume the variance, σ_ϕ to be 1, whereas we assume a higher value of the variance, at 5, so that we get a higher percentage of tax evaders in the model, consistent with the situation for EMDEs (see Dholakia (2022), Hoy et al. (2024), Cobham and Janskỳ (2018)).

4. Results

In this section, we present the Laffer curves derived from equation 61, varying each tax rate from 0 to 100 percent while holding the other tax rates and parameters constant. We also show the impact of a change in the institutional structure of the economy through changes in the probability of getting caught, μ, the penalty on tax evasion, π, the share of non-Ricardian households in the economy, ω, and the mean of the distribution of the disutility parameter, μ_ϕ. This analysis allows us to understand the impact of better quality of institutions on the tax revenues and the optimal tax rates in an EMDE context.[48]

Proposition 1. *An economy with weaker institutions leads to a lower tax compliance by its agents, and the economy always has a positive share of evaders. In an extreme case where the institutions are extremely weak, all the agents in the economy evade. Formally, for an economy with Ricardian households that evade capital income taxes, τ^k, and labour income taxes, τ^n, and if the probability of getting caught after evasion, $0 \leq \mu \leq 1$ and the amount of penalty to be paid after being caught, $\pi > 0$ measure the quality of institutions, assuming $\eta > 1$, the following holds along the balanced growth path.[49] For extremely weak institutions, such that $\mu \to 0$, the proportion of honest taxpayers goes to null, i.e. $\gamma(\hat{\phi}_t^r) \to 0$. When $0 < \mu(1+\pi) < 1$ then the proportion of Ricardian households who choose to be honest, $\gamma(\hat{\phi}_t^r) \in (0,1)$.*

Proof. When $0 \leq \mu(1+\pi) < 1$, from equations 44 and 51, $k_t^{re} > k_t^{rh}$. Further, from equations 49 and 56, $c_t^{re} > c_t^{rh}$. From equations 47 and 54, both $n_t^{rh} \lesseqgtr n_t^{re}$ is possible. When $n_t^{rh} > n_t^{re}$, $u(c_t^{re}, n_t^{re})_{partial} > u(c_t^{rh}, n_t^{rh})$ since $u'_{c,t} > 0$ and $u'_{n,t} < 0$. When $n_t^{rh} < n_t^{re}$, from equations 8 and 16, for a given level of wages, a household would choose the level of n_t^{re} and n_t^{rh} such that $\frac{u'_{n_t^{re}}}{u'_{c_t^{re}}}\frac{u'_{c_t^{rh}}}{u'_{n_t^{rh}}} = \frac{(1-\tau_t^n\mu(1+\pi))}{(1-\tau_t^n)}$ and this would imply that $u(c_t^{re}, n_t^{re})_{partial} > u(c_t^{rh}, n_t^{rh})$.[50]

1. When $\mu \to 0$, using equation 20, we find that in limits $\hat{\phi}_t^r$ is sufficiently positively large and thus following Lemma 1 all households evade and $\gamma(\hat{\phi}_t^r) \to 0$.
2. When $0 < \mu(1+\pi) < 1$, using equation 20, $0 < \hat{\phi}_t^r < \infty$ and the share of honest taxpayers $\gamma(\hat{\phi}_t^r) \in (0,1)$ using Lemma 1.

[47] Elgin et al. (2021b) provide this cross-country dataset. The values of the share of informal employment are high, at around 70-85 percent, for the countries we have considered.

[48] In the results that follow, we assume that $k_t^{rh}, k_t^{re} \in \mathbb{R}_{++}$, , $n_t^{rh}, n_t^{re}, n_t^{nr} \in (0,1)$, and $c_t^{rh}/y_t^r, c_t^{re}/y_t^r, c_t^{nr}/y_t^{nr} \in (0,1)$, in line with economic intuition. We incorporate these conditions in the MATLAB simulations.

[49] Trabandt and Uhlig (2011) take the value $\eta = 2$ in their baseline calibration. We take $\eta = 1.2$ as mentioned in Section 3.

[50] Detailed proof is provided in Technical Appendix Section A.A.5.

□

Proposition 2. *In the presence of strong institutions, tax compliance by individuals in an economy is high, and the proportion of evaders can be null. Formally, for an economy with Ricardian households that evade capital income taxes, τ^k, and labour income taxes, τ^n, and if probability of getting caught after evasion, $0 \leq \mu \leq 1$ and the amount of penalty to be paid after being caught, $\pi > 0$ measure the quality of institutions, assuming $\eta > 1$, the following holds along the balanced growth path. For $\mu(1+\pi)$ above a threshold of 1 such that $1 \leq \mu(1+\pi) \leq (1+\pi)$, all the Ricardian households choose to be honest and $\gamma(\hat{\phi}_t^r) = 1$.*

Proof. 1. When $\mu(1+\pi) = 1$, from equations 44 and 51 $k_t^{re} = k_t^{rh}$ and thus from equations 49 and 56, $c_t^{re} = c_t^{rh}$. From equations 8 and 16, $n_t^{re} = n_t^{rh}$, which implies $u(c_t^{re}, n_t^{re})_{partial} = u(c_t^{rh}, n_t^{rh})$. Using equation 20, we find that $\hat{\phi}_t^r = 0$ and the share of honest taxpayers is $\gamma(\hat{\phi}_t^r) = 1$ using Lemma 1.

2. When $1 < \mu(1+\pi) \leq (1+\pi)$, from equations 44 and 51 $k_t^{re} < k_t^{rh}$. Further, $c_t^{re} < c_t^{rh}$ using equations 49 and 56. From equations 47 and 54, both $n_t^{rh} \lesseqgtr n_t^{re}$ is possible. When $n_t^{rh} < n_t^{re}$, $u(c_t^{re}, n_t^{re})_{partial} < u(c_t^{rh}, n_t^{rh})$ since $u'_{c,t} > 0$ and $u'_{n,t} < 0$. When $n_t^{rh} > n_t^{re}$, from equations 8 and 16, for a given level of wages, a household would choose the level of n_t^{rh} and n_t^{re} such that $\frac{u'_{n_t^{re}}}{u'_{c_t^{re}}}\frac{u'_{c_t^{rh}}}{u'_{n_t^{rh}}} = \frac{(1-\tau_t^n\mu(1+\pi))}{(1-\tau_t^n)}$ and this would imply that $u(c_t^{re}, n_t^{re})_{partial} < u(c_t^{rh}, n_t^{rh})$.[51] Thus, $-\infty < \hat{\phi}_t^r < 0$ and the share of honest taxpayers $\gamma(\hat{\phi}_t^r) = 1$ using equation 20 and Lemma 1.

□

4.1. Laffer Curves

To understand the significance of the heterogeneity assumed in the model in the form of non-Ricardian and Ricardian households, we present Figure 8. Additionally, Table 3 reports the average statutory tax rate and the optimal tax rates for the same. The figure shows the capital, labour, and consumption tax Laffer curves derived from the present benchmark model (blue lines) in comparison to the Laffer curves derived from a model with only Ricardian households (red lines), i.e., $\omega = 0$. Thus, the red line curves are comparable to AEs with low informal sectors and lower tax exemptions, and the blue line curves capture the scenarios in EMDEs with large informal sectors and higher tax exemptions. Tax rates are varied from 0 to 100 percent. A black vertical line shows the average statutory tax rate between 2005-2019.[52] We achieve optimal statutory tax rates at the peak of the Laffer curve. The case with only Ricardian households (red lines) is similar to Trabandt and Uhlig (2011). The first observation we have from these Laffer curves is that, as compared to the present benchmark model, the model with only the Ricardian sector has much higher tax revenues. In simple words, the tax capacity of an economy is characterized by large informal sectors is reduced

[51] Detailed proof is provided in Technical Appendix Section A.A.5.

[52] Details regarding the calculation and the average statutory tax rates have been provided in the Calibrations Section 3 and Data Appendix Section B.B.2. See Table 1.

significantly. For similar tax rates, the tax revenues for the EMDEs are 40-50 percent less for both the capital income taxes and the labour income taxes than the AEs.

[INSERT FIGURE 8 and TABLE 3]

The second observation we have is that the economy is located on the left side of the optimal tax rates on the Laffer curve, where the tax revenues are still an increasing function of tax rates for the given parametric configuration and initial values. The gap of the actual tax rates from the optimal tax rates is much higher for the economies with non-Ricardian households than those with only Ricardian households. The same is being summarized in first two rows of Table 3. Next, we look at the maximum additional tax revenues (in percentage) that can be generated by moving from the average statutory tax rate to the peak of the Laffer curve. For the present benchmark model, moving to the optimal capital tax rate increases tax revenues by 3.9 percent, while moving to the optimal labour tax rate increases revenues by 3.23 percent. The consumption tax Laffer curves do not peak similar to the standard result in any general equilibrium setup (Trabandt and Uhlig (2011) and Nutahara (2015)). This is because the marginal distortion is lower than the benefit from increasing tax rates for all tax rates for the case of consumption taxes.[53]

In Table 3, we also report results on the degree of self-financing, i.e., the percentage of loss in tax revenues due to a 1 percent cut in tax rates, that can be recovered through the general equilibrium effects. Such effects occur as the households' decision on the supply of labour and capital depends on the labour and capital tax rates, respectively (equations 48 and 55 for labour, and equations 45 and 52 for capital). Usually, with a fall in the tax rates households increase their supply of labour and capital and this would increase the tax revenues. In the present model along with these general equilibrium effects, there is an additional channel which affects the labour supply and that is the tax compliance channel explained in the previous sections. Since the decision to evade taxes or be honest is endogenous it also depends on the tax rates and thus it affects the total tax revenues. We have used the formula proposed by Trabandt and Uhlig (2011) to calculate the percentage of self-financing as follows,

$$Self financing(\%) = \left(1 - \frac{\frac{\partial T_t}{\partial \tau_t^x}}{\frac{\partial T_t|_{NF}}{\partial \tau_t^x}}\right) * 100 \tag{62}$$

where τ_t^x represents the tax rate on labour income (τ_t^n) or capital income (τ_t^k). The term in the numerator, $\frac{\partial T_t}{\partial \tau_t^x}$, denotes the change in total tax revenues T_t (given by equation 38), when the tax rate on capital or labour is changed by 1 percent. Specifically, $\frac{\partial T_t}{\partial \tau_t^n} = T_t(\tau_t^k, \tau_t^n - 0.01, \tau_t^c) - T_t(\tau_t^k, \tau_t^n, \tau_t^c)$ is the change in tax revenues when the labour tax rate is decreased by 1 percent, holding the other tax rates constant, and $\frac{\partial T_t}{\partial \tau_t^k} = T_t(\tau_t^k - 0.01, \tau_t^n, \tau_t^c) - T_t(\tau_t^k, \tau_t^n, \tau_t^c)$ is the change in tax revenues

[53] Hiraga et al. (2018) showed that the shape of the Laffer curve depends on the relative price of leisure as well as the form of the utility function. The authors find that the utility function used in Trabandt and Uhlig (2011) and Nutahara (2015) will always lead to a monotonically increasing Laffer curve in consumption, whereas a utility function that is additively separable in consumption and labour supply may lead to a hump-shaped consumption Laffer curve. Their result are not affected by the inclusion of agent heterogeneity.

when the tax rate on capital is decreased by 1 percent, holding other tax rates constant. The term in the denominator, $\frac{\partial T_t|_{NF}}{\partial \tau_t^x}$, provides the change in the tax revenues when there are no feedback effects, i.e., no endogenous changes in economic variables in response to changes in the tax rates. In the absence of feedback effects, we get the loss in the tax revenue due to a 1 percent decrease in the labour tax rate as $\frac{\partial T_t|_{NF}}{\partial \tau_t^n} = (1-\omega)[\overline{\gamma} w_t^r \overline{n^{rh}} + (1-\overline{\gamma})\mu(1+\pi) w_t^r \overline{n^{re}}]$, while that for a 1 percent decrease in the capital tax rate is given as $\frac{\partial T_t|_{NF}}{\partial \tau_t^k} = (1-\omega)[\overline{\gamma}(d_t-\delta)\overline{k^{rh}} + (1-\overline{\gamma})\mu(1+\pi)(d_t-\delta)\overline{k^{re}}]$. If there are no endogenous feedback effects of a change in tax rate τ_t^x, then $\frac{\partial T_t}{\partial \tau_t^x} = \frac{\partial T_t|_{NF}}{\partial \tau_t^x}$, i.e., the loss in tax revenues from a 1 percent decrease in the tax rate will be the direct loss in tax revenues when there are no feedback effects, and we obtain $Self - financing = 0\%$. On the other end, if the feedback effects are strong enough to completely offset the loss in tax revenues due to a 1 percent decrease in tax rate (for instance, through an increase in labour supply, capital, consumption, or tax compliance, as a result of increased income due to lower tax rate), we obtain $\frac{\partial T_t}{\partial \tau_t^x} = 0$ and $Self - financing = 100\%$. This means that feedback effects fully compensate for the loss in tax revenues arising out of the lower tax rates, and the policy to lower the tax rate is entirely self-financing.

Table 3 shows that for both capital and labour tax Laffer curves, the degree of self-financing through the tax compliance channel (gap between row 4 and row 5) is much stronger in the EMDEs (model economy with non-Ricardian households) than in the AEs (model economy with only Ricardian households). However, the overall degree of self-financing is lower for the present benchmark model than for the model with only Ricardian households. This is consistent with the literature showing that the labour supply channel is weak in the EMDEs (Armangué-Jubert et al. (2023)).

4.2. Comparative Statics

In this section, we study what happens to the optimal tax rates and the tax revenues as the institutional structure of an economy changes. To conduct this analysis, we consider four features of the model economy: i) the probability of getting caught in tax evasion, μ, which captures the percentage of tax evaders that are caught by the government. A higher value of μ indicates better tax effort on the part of the government, and thus leads to higher tax revenues due to improved compliance (Propositions 1 and 2); ii) the penalty on tax evasion, π, which captures the monetary penalty that is to be paid by a tax evader, if caught. A higher value of π indicates commitment of the government to reduce tax evasion, and thus leads to a higher tax revenue by improving tax compliance (Propositions 1 and 2); iii) the percentage of non-Ricardian households, ω, captures the percentage of tax-exempt households in an economy. A reduction in ω, i.e., bringing more people into the tax collection net leads to higher tax revenues; iv) improving compliance norms of the society which is captured by the mean of the distribution of the disutility parameter, μ_ϕ, which indicates the mean level of disutility felt by an individual in the society if caught evading taxes. A higher mean would indicate higher disutility on an average, and thus a culture in favour of tax compliance in the economy. This should reduce tax evasion and increase tax revenues. Figures 9-12 and Tables 4-7 below, show the comparative statics for each of the parameters mentioned above in the model one by one with its implications, when the rest of the model is kept unchanged.

Figure 9a shows the capital tax Laffer curves for three values of the probability of getting caught, $\mu \in \{0.02, 0.05, 0.10\}$, i.e., for the value of the probability at 2 percent, 5 percent, and 10 percent. As the value μ increases, we find that the Laffer curve shifts upwards and to the left. This means that with stricter institutions as the probability of getting caught increases, the tax revenues increase and even the optimal tax rates fall. Figure 9b summarizes this result as it shows the path of optimal tax rates and the tax revenues along the balanced growth path, as μ goes from 1 percent to 10 percent. We observe that as μ increases, the optimal capital tax rate falls and the tax revenues at the peak of the Laffer curve rise.[54] This primarily occurs due to the reduction in tax evasion, or an increase in $\gamma(.)$, the proportion of honest taxpayers in the economy, as μ rises, as can be seen in Figure 9c. The formal proof of this result is presented in Propositions 1 and 2. This result is consistent with the literature (Papp and Takáts (2008), Kleven et al. (2011), Advani et al. (2023), Banerjee et al. (2022)). Households are incentivised to be honest as the cost of getting caught outweighs the benefits of tax evasion. The optimal tax rate on capital falls, which further incentivises tax compliance. As a result of increased tax compliance as well as increased probability of getting caught, the tax revenues rise. We observe similar results for labour tax Laffer curves, in Figures 9d, 9e and 9f. At the average statutory tax rate considered, the tax revenues increase by about 23 percent and 17 percent for labour and capital income taxes respectively with an increase in μ from 1 percent to 10 percent. For consumption tax Laffer curves, as shown in Figures 9g and 9h, the optimal tax rate does not change. However, the tax revenues are rising along the balanced growth path. Table 4 reports the optimal tax rates, and the percentage increase in tax revenues at the optimal tax rate, as μ increases. We find that the degree of self-financing increases as the probability of getting caught increases. Also, the self-financing channel is stronger in the capital taxes than the labour taxes.[55]

[INSERT FIGURE 9 AND TABLE 4]

Figure 10a presents the results for changes in the penalty on getting caught, $\pi \in \{1, 3, 5\}$, i.e., for the penalty on tax evasion being equal to, three times, and five times, the amount of tax evaded, when capital tax rates are optimised. Capital tax Laffer curves shift upward and to the left. As the penalty on tax evasion rises, tax revenue increases although the optimal tax rates on capital fall. This is also summarized in Figure 10b. This happens primarily because tax evasion falls (i.e. $\gamma(.)$ rises), as also seen in Figure 10c. The results observed for changes in the penalty on getting caught evading taxes are qualitatively similar to the ones observed for changes in the probability of getting caught. This observation is partly explained through Propositions 1 and 2. Figures 10d and 10e present results for changes in the penalty on getting caught, π, when labour tax rates are

[54] The results are at the balanced growth path, at the optimal rate of capital tax, while leaving the other two tax rates fixed at the average.

[55] Figures C.1, C.2 and C.3 in Appendix C.1.1 provide further insight into what happens in the economy as probability of getting caught increases.

optimised. We observe a slight difference here, as the optimal tax rates also rise along with a rise in tax revenues. However, looking at Figure 10d, we can see that with a rise in π, tax revenues increase even at lower tax rates, as the Laffer curves for a higher level of π are at all points above those for lower levels of π. This is because tax evasion falls as the penalty on tax evasion rises, as seen in Figure 10f. Table 5 reports optimal tax rates and the percentage increase in tax revenues, as π increases. The tax revenues from capital and labour taxes rise by about 2 percent and 3.5 percent respectively when π increases from 1 to 5. Figures 10g and 10h provide results for consumption tax Laffer curves. We observe that the optimal tax rate does not change, but tax revenues rise slightly.[56].

[INSERT FIGURE 10 AND TABLE 5]

Both these parameters discussed above are indicators of the strength of the institutions, and an increase in either of these disincentivizes tax evasion and increases the percentage of honest taxpayers in the economy but the results are stronger for the change in the probability of auditing than the punitive action. Propositions 1 and 2 provide us formal proofs with combinations of these two features. The next two features we would discuss concern the longstanding features of the economy and would thus require more effort to break it through. The first is the tax compliance norms in the country. This concerns the behavioural aspect of the agents in the economy and how they align themselves to those norms. For this we consider the changes to the mean of the level of disutility parameter in the economy, μ_ϕ. The disutility parameter in the economy, ϕ^r, follows a lognormal distribution in our model. A country where acceptance to the corrupt practices is high would have a lower mean of the disutility parameter and high otherwise. As discussed in Figure 4 of Section 1.1.1, on average the AEs have lower corruption index and the EMDEs have high corruption index. Besley and Persson (2014) also discusses how the EMDEs have lower tax compliance norms than the AEs.[57] As the mean of the distribution increases, on average, the households feel a higher level of disutility on getting caught evading taxes. Thus, a higher mean corresponds to an economy that is averse to tax evasion. As a result, the percentage of honest taxpayers, $\gamma(.)$, rises, and the optimal tax rates fall.

[INSERT FIGURE 11 AND TABLE 6]

Figure 11 provides an analysis of the economy as the mean of the disutility distribution changes. We show Laffer curves for $\mu_\phi \in \{0, 1, 2\}$.[58] Further, Table 6 reports the optimal tax rates, and the percentage increase in tax revenues as μ_ϕ increases, for the capital and labour tax Laffer curves respectively. We observe that as μ_ϕ rises, the optimal tax rates on capital and labour fall, and the tax revenues increase. Laffer curves for capital and labour shift upwards and to the left as the mean

[56] Further results for the economy are provided in Figures C.4, C.5 and C.6 in Appendix C.1.2.

[57] Papp and Takáts (2008) fix the mean of this variable, and do not look at how variations in the culture and beliefs regarding government and corruption in an economy can affect tax compliance and tax revenues.

[58] Figures C.7, C.8 and C.9 in Appendix C.1.3 provide detailed insights.

increases. For the average statutory tax rate considered, the tax revenues increase by 11 percent and 14 percent for the capital and labour taxes, respectively, when μ_ϕ increases from 0 to 3. For the consumption tax Laffer curves, even though the optimal tax rate does not change, the tax revenues increase as μ_ϕ rises. Thus, fostering a culture of tax compliance in the economy can lead to more fiscal space for the government to increase tax revenues and lower tax rates. Similar to previous cases, Table 6 shows that the self-financing channel is stronger for capital taxes than for labour taxes.

The next feature of the economy we consider is the share of non-Ricardian households, ω, that is associated with the level of tax exemptions in an economy and size of the shadow economy. Figure 12 provides an analysis of the economy.[59] The Laffer curves are shown for $\omega \in \{0.55, 0.75, 0.90\}$, i.e., the share of non-Ricardian households in the economy being 55 percent, 75 percent, and 90 percent in the Figures 12a, 12d and 12g. As ω falls, the optimal tax rates fall and the tax revenues rise. This relationship is also summarized in the Figures 12b, 12e and 12h. For the average statutory tax rates considered, the tax revenue increases by more than 400 percent when the non-Ricardian share falls from 90 to 55 percent for the capital and labour taxes. The reduction in tax rates increases tax compliance, thus further raising the tax revenues. Table 7 reports values of the optimal tax rates and the percentage increase in tax revenues as ω falls. There is a significant shift in the consumption tax Laffer curves as ω changes. With a fall in ω, tax revenues increase while the optimal consumption tax rate stays the same. This is from a pure increase in the share of households paying taxes on consumption and labour. The general equilibrium effects of both the labour supply and the tax compliance channel increase as more and more people are brought under the tax collection net.

[INSERT FIGURE 12 AND TABLE 7]

4.3. Policy experiments

We conduct two thought experiments to show some policy implications of our model. The first experiment has to do with the decision of the government to increase the expenditure on auditing the taxpayers to increase tax revenues. Recently, Boning et al. (2025) empirically showed that one USD spent in auditing taxpayers above the 90th income percentile yields more than 12 USD in revenues. In the absence of data, we can use the present model and get some estimates. The increase in the audit would make evasion more difficult by increasing the probability of getting caught, and as shown in the results Section 4.4.2 this would lead to an increase in the tax revenues. We provide some estimates to the cost incurred and revenues gained from such an exercise. If the cost of increasing audit probability is less than the rise in tax revenues, then the government should deploy more inputs into auditing, otherwise not.

[INSERT TABLE 8 AND TABLE 9]

[59] Refer to Figures C.10, C.11 and C.12 in Appendix C.1.4 for further details.

Table 8 shows the results of a 1 percent, 3 percent, 5 percent, and 8 percent increase in the probability of getting caught, starting from the calibrated level of μ at 2 percent.[60] In other words, the rows refer to $\mu = 0.03, 0.05, 0.07$ and 0.10. Columns 3 and 4 show the percentage change in the total tax revenue, TR and percentage change in the tax-to-GDP ratio, TR/y. As shown previously we can see that both TR and TR/y would increase. For instance, a five percent increase in the audit probability can increase tax revenues by up to 12 percent and tax-to-GDP ratio by up to 8 percent. This result assumes that the choice of tax compliance by households and thus $\gamma(.)$ is endogenous. To separate out the tax compliance channel we fix $\gamma = 53.90$ percent, i.e. value of $\gamma(.)$ we get for the benchmark case of $\mu = 0.02$, for columns 5-7. When the audit probability is increased by 5 percent, out of the total increase in TR and TR/y, around 6 percent and 4 percent increase occurs due to the tax compliance channel, respectively. A one percent increase in μ increases tax revenues by 3.65 percent when γ is endogenous and by 1.25 percent when γ is fixed. The remaining, i.e., 2.4 percent, which constitutes about 66 percent of the increase in tax revenues, comes from an increase in tax compliance, from 53.90 percent to 57.50 percent. With an 8 percent increase in μ, tax revenues increase by 16.58 percent when γ is endogenous, while with exogenous γ, tax revenues increase by 9.97 percent. The remaining, i.e., 6.61 percent, comes from an increase in tax compliance, which constitutes about 40 percent of the increase in tax revenues. If the cost of increasing the audit probability is less than the tax revenue gains in TR, then it is profitable to invest more in tax audits. Further, we observe that tax revenues as a share of GDP, i.e., TR/y, also increase by between 2.29 percent and 10.22 percent with a 1-8 percent increase in μ. If the increase in the probability of auditing involves a one time technology upgrade, then the rise in tax revenues would happen for more than one year.

The second experiment we do is to show why consumption taxes, which are also indirect taxes, have equity concerns.[61] A one percent rise in the consumption tax will impact Ricardian and non-Ricardian households differently. Table 9 shows the effects of an increase in the consumption tax rate τ_t^c by 1 percent, 3 percent, 5 percent, and 10 percent, from the benchmark tax rate given in Table 1. When the consumption tax increases, both consumption as well as the labour supply by the households fall for all types of households qualitatively. The consumption falls due to price effect of the increase in the consumption taxes and since the real wages in the labour supply equations of the households (equations 8, 16, and 23) fall, the labour supply also falls. The fall in the consumption for the non-Ricardian households is higher than for the Ricardian households. However, the fall in labour supply is higher for the Ricardian than for the non-Ricardian households. A fall in consumption leads to a reduction in the household utility, whereas a fall in labour supply or increase in leisure leads to an increase in utility. On aggregation, we observe that the total utility for the Ricardian households, $\overline{u^r}$ rises with a 1-5 percent increase in the consumption tax, while it falls for the non-Ricardian households depicted by $\overline{u^{nr}}$.[62] Total economy-wide utility, $\overline{u}$,

[60] Tax rates τ^k, τ^n and τ^c are fixed throughout this exercise to values provided in the Table 1.

[61] Since the Laffer curve analysis of finding the optimal tax rates breaks down for the consumption taxes in the general equilibrium setup, we show an alternate result here.

[62] We obtain $\overline{u^r}$ as $(1-\omega)(\gamma(.)u(\overline{c^h}, \overline{n^h}) + (1-\gamma(.))u(\overline{c^e}, \overline{n^e}))$ and we obtain $\overline{u^{nr}}$ as $\omega u(\overline{c^{nr}}, \overline{n^{nr}})$.

falls for all cases. Thus, a rise in the consumption tax disadvantages the non-Ricardian households more. The consumption or indirect taxes are said to be regressive as they affect the poor more than the rich. Heathcote (2005) constructs a model with agents differing in income and wealth levels, where borrowing is not permitted. The authors find that a rise in the consumption tax has a larger impact on low-wealth households who are constrained for borrowings as well as low on assets. Schechtl (2024) also shows that amongst OECD countries, a higher consumption tax is associated with a higher level of poverty. On the other hand, Ma (2019) shows that a rise in tax progressivity leads to an increase in consumption and employment for the poor and a fall in consumption for the rich. In our model, consumption taxes affect the non-Ricardian households more than the Ricardian households. For this reason, we leave the consumption tax out from our main analysis.

5. Conclusion

Tax revenues as a share of GDP are lower in the EMDEs as compared to the AEs. This paper attempts to quantify the possible ways in which the EMDEs can improve their tax-to-GDP ratio using a theoretical framework and provides some insights. We do this using a Laffer curve analysis at the balanced growth path. We construct a closed-economy discrete-time neoclassical growth model with heterogeneous agents, and three sectors: households, firms, and the government. The model adds two features of the EMDEs to the standard model that limit the tax capacity of the EMDEs. These are well documented in the literature. The first feature we model is the presence of a large proportion of the economy that is not paying taxes and is not even filing taxes. This happens for reasons including tax exemptions to certain sectors (like agricultural incomes are tax-exempt in India), tax exemptions to individuals below a certain income threshold, and the large informal sectors in EMDEs. We incorporate this feature in the model as heterogeneous agents with Ricardian and non-Ricardian households. The non-Ricardian households are completely exempt from paying taxes and the Ricardian households can choose to be tax-compliant or not. This makes the extent of tax evasion partially endogenous in the model. The second feature we exploit extensively is the quality of institutions measured by the corruption control, governance, and complexity of the tax system. Such systems are weaker in the EMDEs as opposed to the AEs. We add features like the probability of audit, penalty on evasion, and culture of corruption in a minimalistic way to capture the essence of weak institutions in EMDEs. To the best of our knowledge, such a coherent neoclassical growth model setup does not exist in the literature that captures these features in the EMDEs well.

We find that fiscal policies attuned towards bringing a higher percentage of agents under the ambit of tax collection -despite households evading taxes- improve the tax revenues significantly. The tax revenues can increase by more than 50 percent for both capital and labour income taxes in the EMDEs when all the households are Ricardian. The model clearly shows that countries with weaker institutions will have a lower tax capacity as any increase in the tax rates reduces tax compliance and increases tax evasion. We find that improving the quality of institutions by more tax audits can increase the tax revenues by 17 percent and 23 percent for the capital and labour income taxes, respectively, by improving tax compliance. Punitive actions like increasing the penalties for tax evaders can also increase the tax revenues by 2 percent for the capital tax and 3.5 percent for the labour tax by improving tax compliance. Improved societal norms for tax compliance (higher mean of the disutility parameter) can also increase the tax revenues by 11 and 14 percent for the capital and labour income taxes, respectively, on the balanced growth path. As a future research work, one possible extension could be how digitization of tax payments can affect the tax to GDP ratio and tax compliance channel in the presence of an active fiscal policy.

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Figures and Tables

Figures

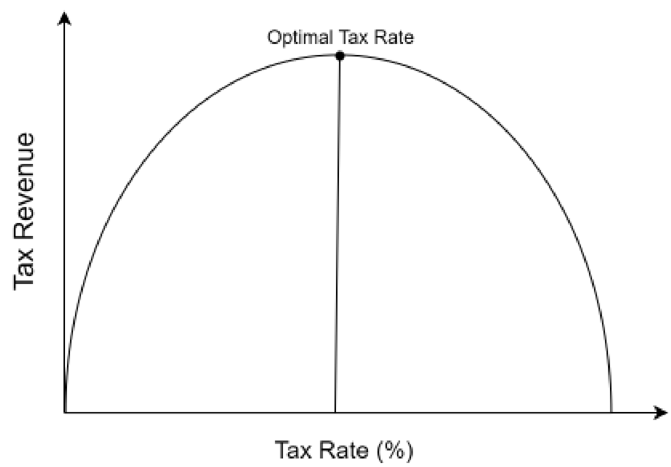


Figure 1: Laffer Curve

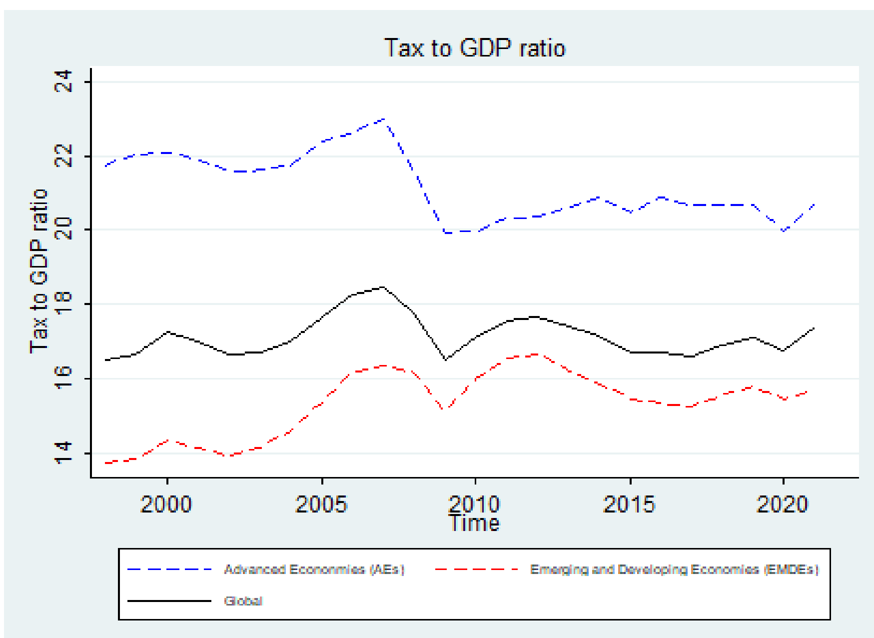


Figure 2: Tax to GDP Ratio (%)

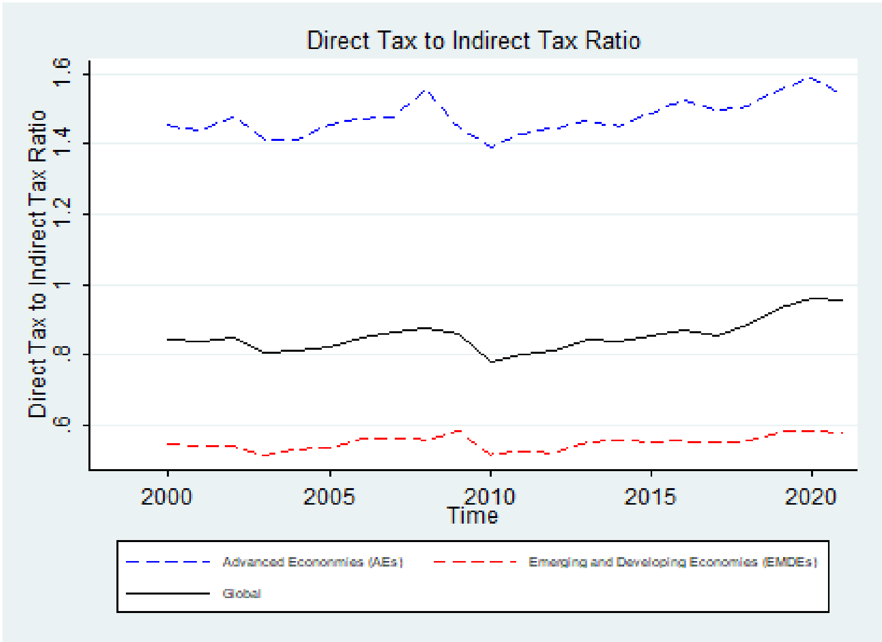


Figure 3: Direct to Indirect Tax Ratio

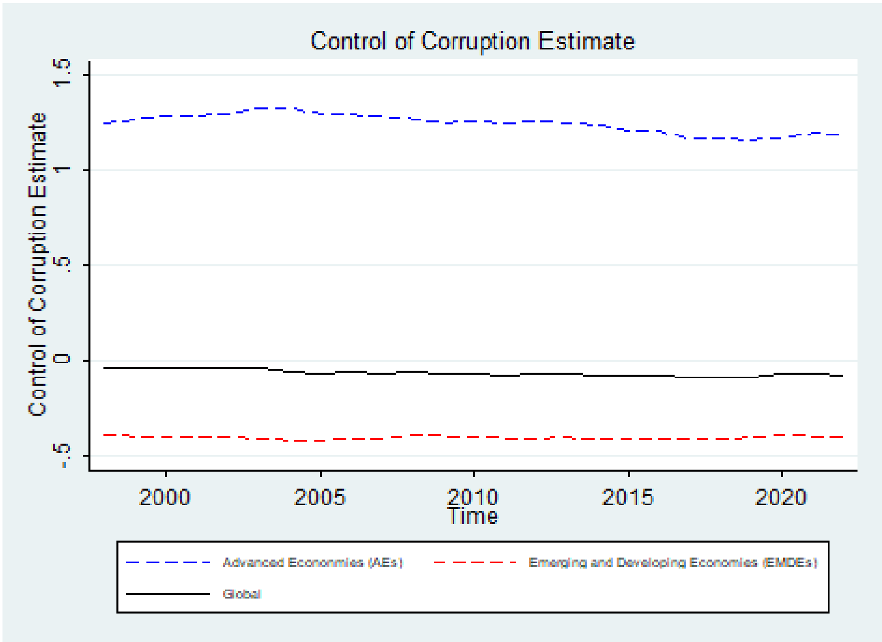


Figure 4: Control of Corruption

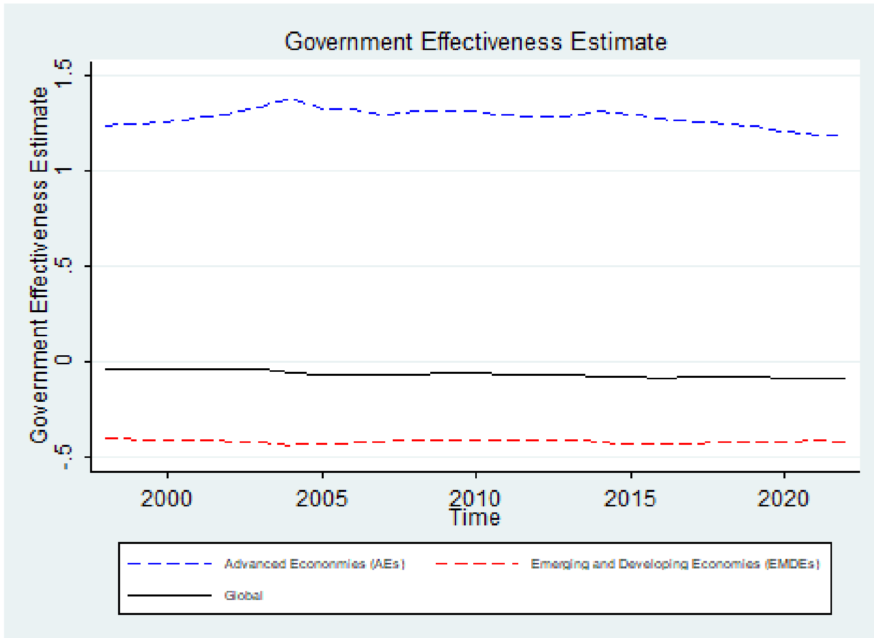


Figure 5: Government Effectiveness

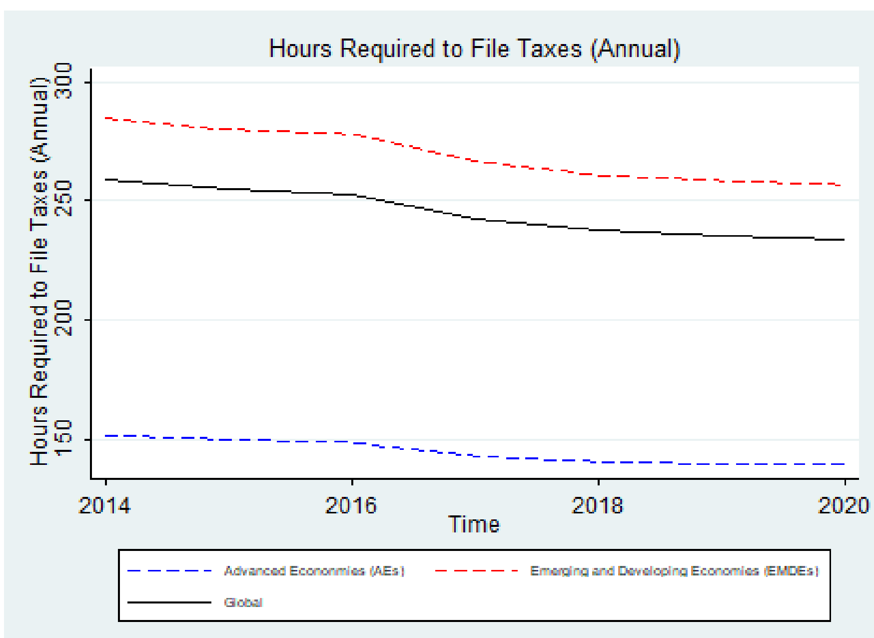


Figure 6: Hours Taken to File Taxes (Annual)

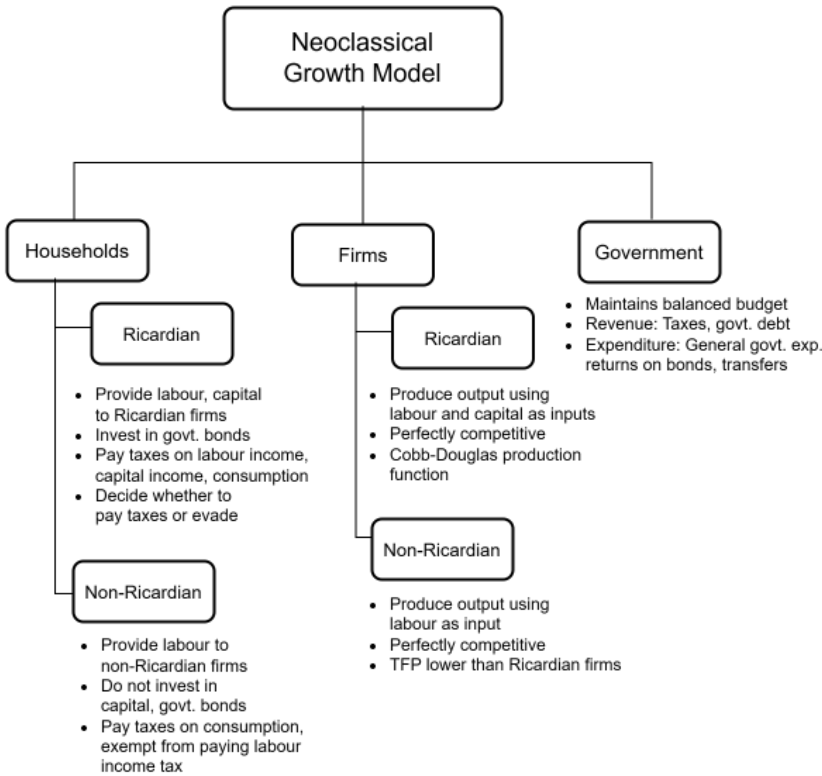


Figure 7: Overview of the Model

Calibration Tables

Table 1: Initial Values for Variables

Variable	Notation	Value	Source
Households			
Capital stock to GDP: Honest	$\overline{k^{rh}/y^r}$	3.27	Feenstra et al. (2015)
Capital stock to GDP: Evading	$\overline{k^{re}/y^r}$	3.27	Feenstra et al. (2015)
Investment to GDP: Honest	$\overline{x^{rh}/y^r}$	0.29	World Bank (2024d)
Investment to GDP: Evading	$\overline{x^{re}/y^r}$	0.29	World Bank (2024d)
Consumption to GDP: Honest	$\overline{c^{rh}/y^r}$	0.72	World Bank (2024d)
Consumption to GDP: Evading	$\overline{c^{re}/y^r}$	0.72	World Bank (2024d)
Consumption to GDP: Non-Ricardian	$\overline{c^{nr}/y^{nr}}$	0.72	World Bank (2024d)
Labour supply: Honest	$\overline{n^{rh}}$	0.40	Feenstra et al. (2015)
Labour supply: Evading	$\overline{n^{re}}$	0.40	Feenstra et al. (2015)
Labour supply: Non-Ricardian	$\overline{n^{nr}}$	0.50	Raveendran and Vanek (2020), Bank (2020), Yu (2004), GOV (2023)
Government			
Government debt to GDP	$\overline{b/y}$	0.53	World Bank (2024d)
Govt. consumption to GDP	$\overline{g/y}$	0.10	World Bank (2024d)
Government transfers to GDP	$\overline{s/y}$	0.06	Calculated by Authors
Capital tax rate	$\overline{\tau^k}$	0.29	World Bank (2024c)
Labour tax rate	$\overline{\tau^n}$	0.32	World Bank (2024c)
Consumption tax rate	$\overline{\tau^c}$	0.11	World Bank (2024c)
Return on govt. bonds	$\overline{R^b}$	1.08	Calculated by Authors

Table 2: Calibration for Parameters

Parameter	Notation	Value	Source
Households			
Share of Ricardian goods	a_r	0.6	Alba and McKnight (2022)
Elasticity of substitution between Ricardian and non-Ricardian goods	ϵ_r	1	Mishra (2022)
Inverse of intertemporal elasticity of substitution	η	1.2	Thimme (2017)
Frisch elasticity: Ricardian	ψ^r	6	Peterman (2016)
Frisch elasticity: Non-Ricardian	ψ^{nr}	8	Peterman (2016)
Weight of Labour: Honest	κ^{rh}	0.90	Calculated by Authors
Weight of Labour: Evading	κ^{re}	1.33	Calculated by Authors
Weight of Labour: Non-Ricardian	κ^{nr}	2.43	Calculated by Authors
Rate of depreciation	δ	0.03	Calculated by Authors
Firms			
Share of capital: Ricardian	θ	0.5	Reserve Bank of India (2024)
Growth rate: Ricardian	ζ^r	1.057	Feenstra et al. (2015)
Growth rate: Non-Ricardian	ζ^{nr}	1.04	Calculated by Authors
Technology/TFP: Ricardian	A^r	1.02	Calculated by Authors
Technology/TFP: Non-Ricardian	A^{nr}	0.25	Calculated by Authors
Government			
Probability of getting caught	μ	0.02	Tandon and Rao (2017)
Penalty on getting caught	π	3	PWC (2024), Papp and Takáts (2008)
Share of non-Ricardian households	ω	0.75	Elgin et al. (2021b)
Disutility parameter	ϕ^r		
Mean	μ_ϕ	0	Papp and Takáts (2008)
Variance	σ_ϕ	5	Calculated by Authors

Laffer Curves

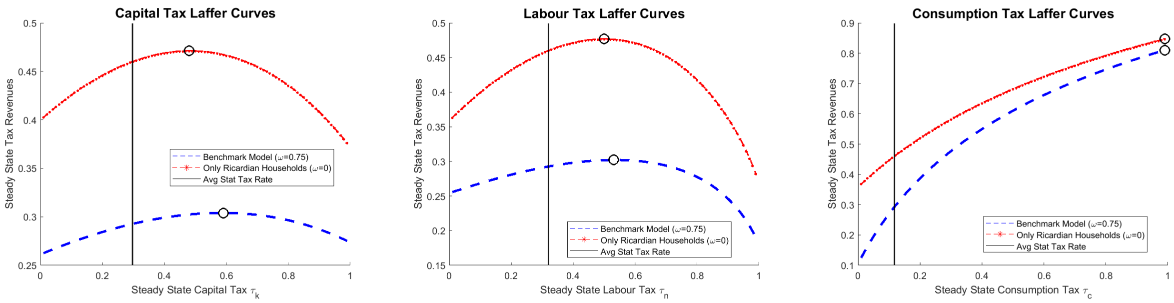


Figure 8: Laffer Curves: Benchmark Model and Model with Only Ricardian Households

Table 3: Average Statutory tax rate, optimal tax rate, maximum additional tax revenues and percentage self financing of a tax cut. All values are in percent.

	Benchmark Model		**Only Ricardian Households**	
	Capital	**Labour**	**Capital**	**Labour**
Average Statutory Tax Rate	29.68	32.04	29.68	32.04
Optimal Tax Rate	59	53	48	50
Maximum Additional Tax Revenue	3.9	3.23	2.42	3.62
Self-financing	40.72	49.75	73.95	68.96
Self-financing (Absence of tax compliance channel)	26.66	26.10	70.52	61.36

Comparative Statics

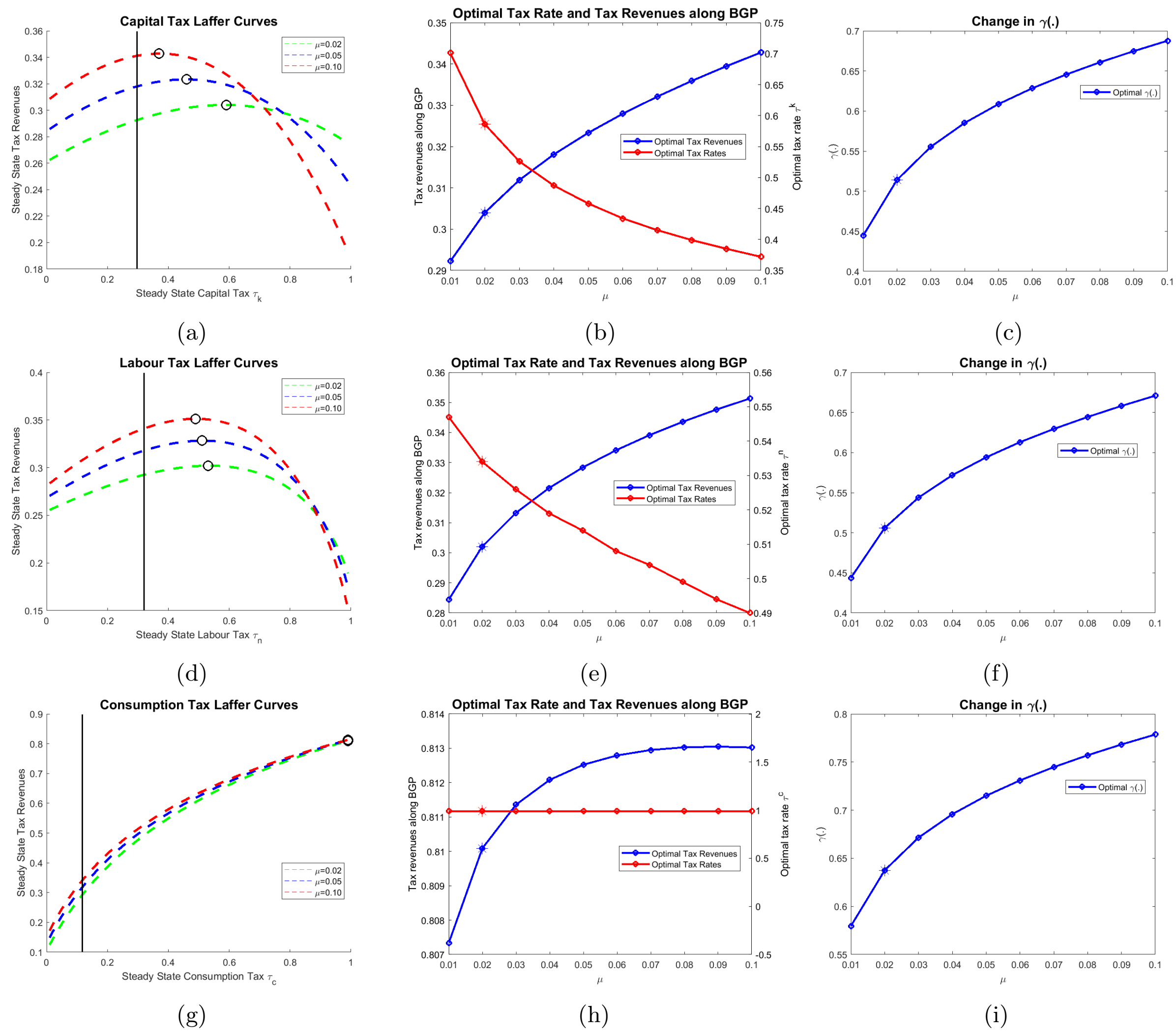


Figure 9: Effects of changes in μ, the probability of getting caught

Table 4: Average Statutory tax rate, optimal tax rate, percentage increase in tax revenues and percentage self financing of a tax cut. All values are expressed in percent.

	Probability of getting caught, μ					
	1%		**5%**		**10%**	
	Capital	**Labour**	**Capital**	**Labour**	**Capital**	**Labour**
Average Statutory Tax Rate	29.68	32.04	29.68	32.04	29.68	32.04
Optimal Tax Rate	59	53	46	51	37	49
Percentage increase in tax revenue	-	-	6.4	6	8.72	7
Self-financing	40.72	49.75	56.62	48.24	73.82	48.68
Self-financing (Absence of tax-compliance channel)	26.66	26.10	47.18	27.78	68.20	40.05

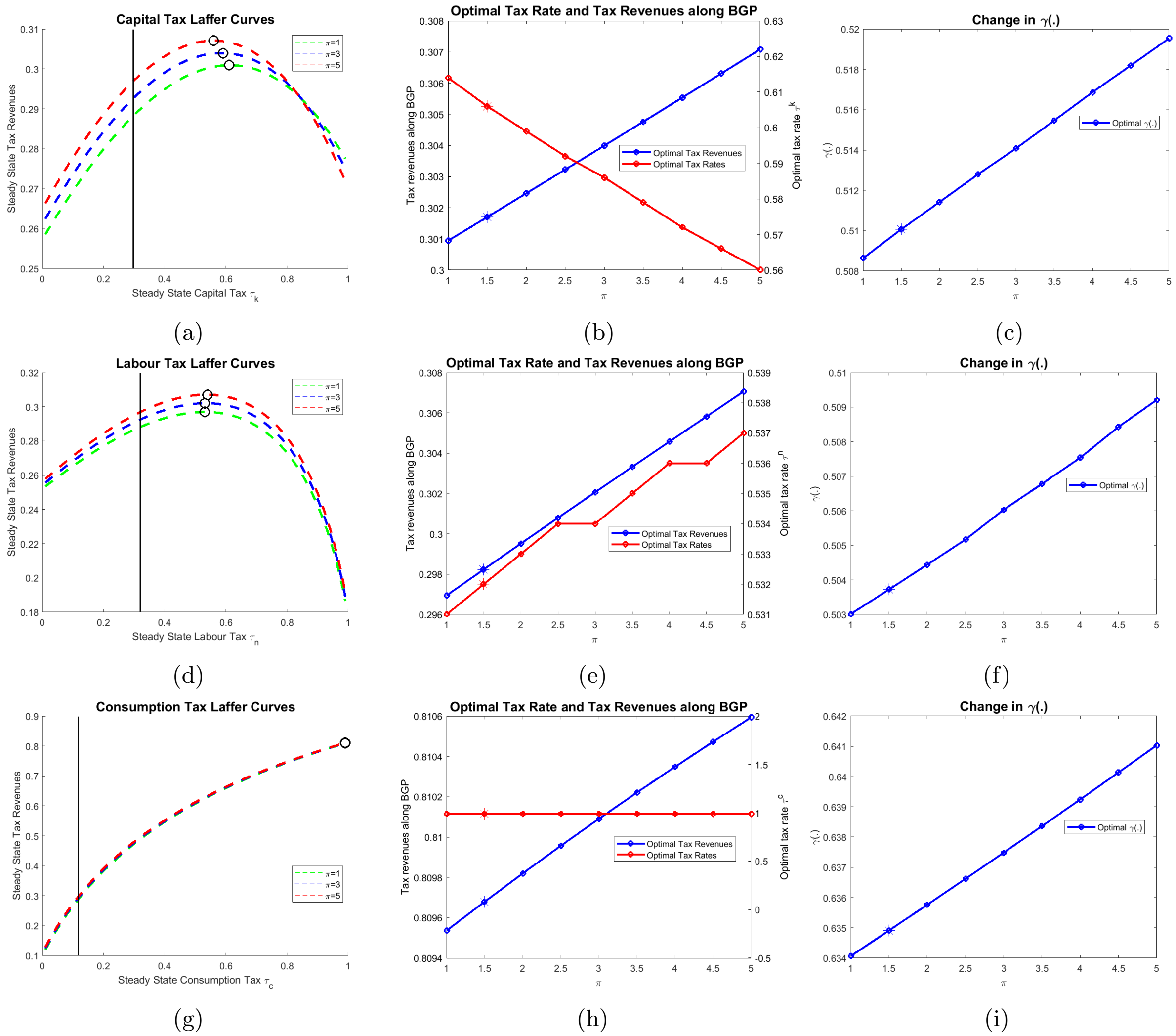


Figure 10: Effects of changes in π, the penalty on tax evasion

Table 5: Average Statutory tax rate, optimal tax rate, percentage increase in tax revenues and percentage self-financing of a tax cut. All values are expressed in percent.

	Penalty on tax evasion, π					
	100%		**300%**		**500%**	
	Capital	**Labour**	**Capital**	**Labour**	**Capital**	**Labour**
Average Statutory Tax Rate	29.68	32.04	29.68	32.04	29.68	32.04
Optimal Tax Rate	61	53	59	53	56	54
Percentage increase in tax revenue	-	-	1.01	1.72	1.02	1.65
Self-financing	38.09	51.23	40.72	49.75	43.38	48.50
Self-financing (Absence of tax-compliance channel)	22.93	25.45	26.66	26.10	30.35	26.82

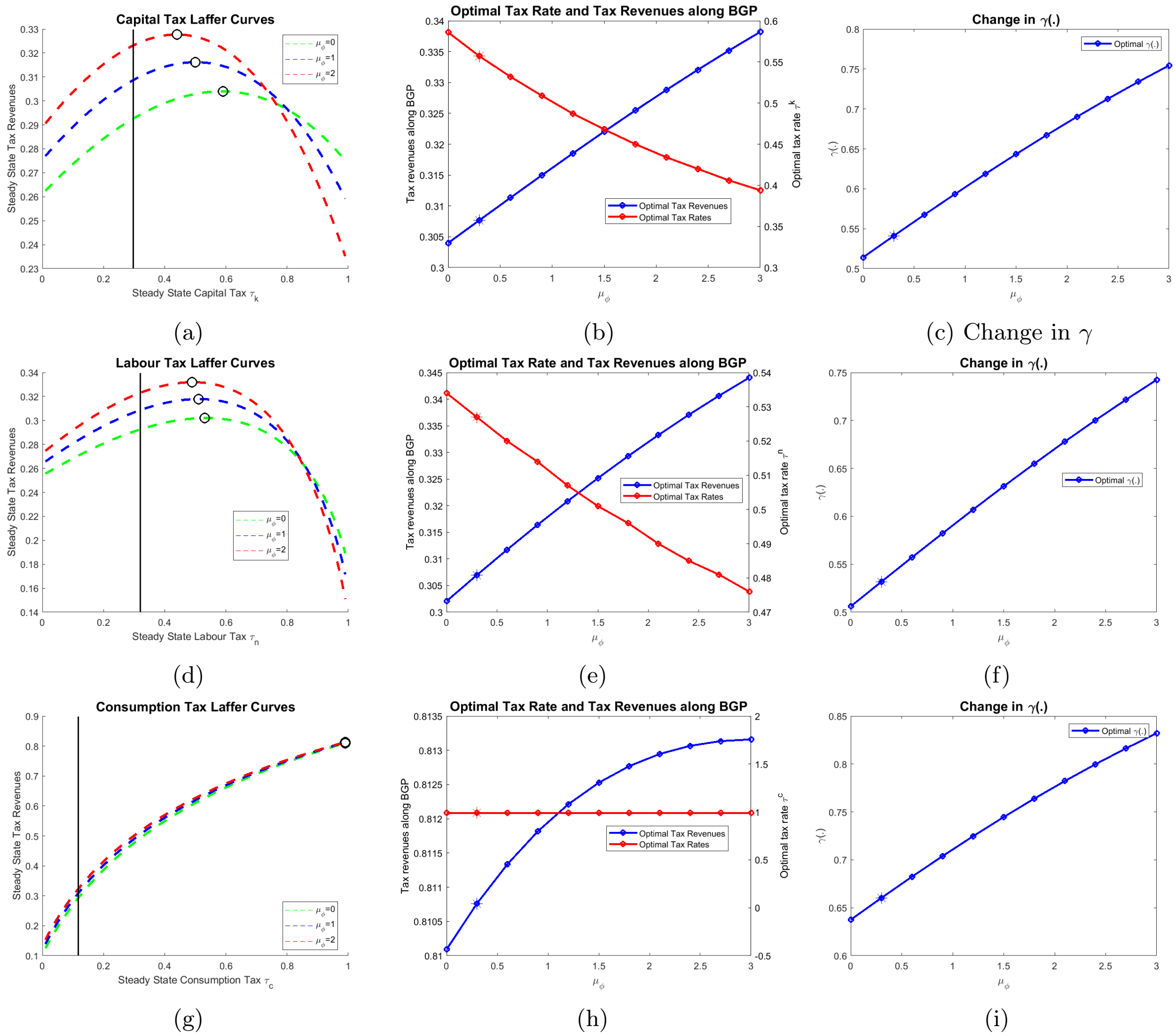


Figure 11: Effects of changes in μ_ϕ, the mean of the disutility parameter

Table 6: Average Statutory tax rate, optimal tax rate, percentage increase in tax revenues and percentage self-financing of a tax cut. All values are expressed in percent.

	Mean of the disutility parameter, μ_ϕ					
	0		**1**		**2**	
	Capital	**Labour**	**Capital**	**Labour**	**Capital**	**Labour**
Average Statutory Tax Rate	29.68	32.04	29.68	32.04	29.68	32.04
Optimal Tax Rate	59	53	50	51	44	49
Percentage increase in tax revenue	-	-	4	5.24	3.66	4.43
Self-financing	40.72	49.75	50.02	50.36	59.40	51.17
Self-financing (Absence of tax-compliance channel)	26.66	26.10	38.57	31.32	50.28	36.18

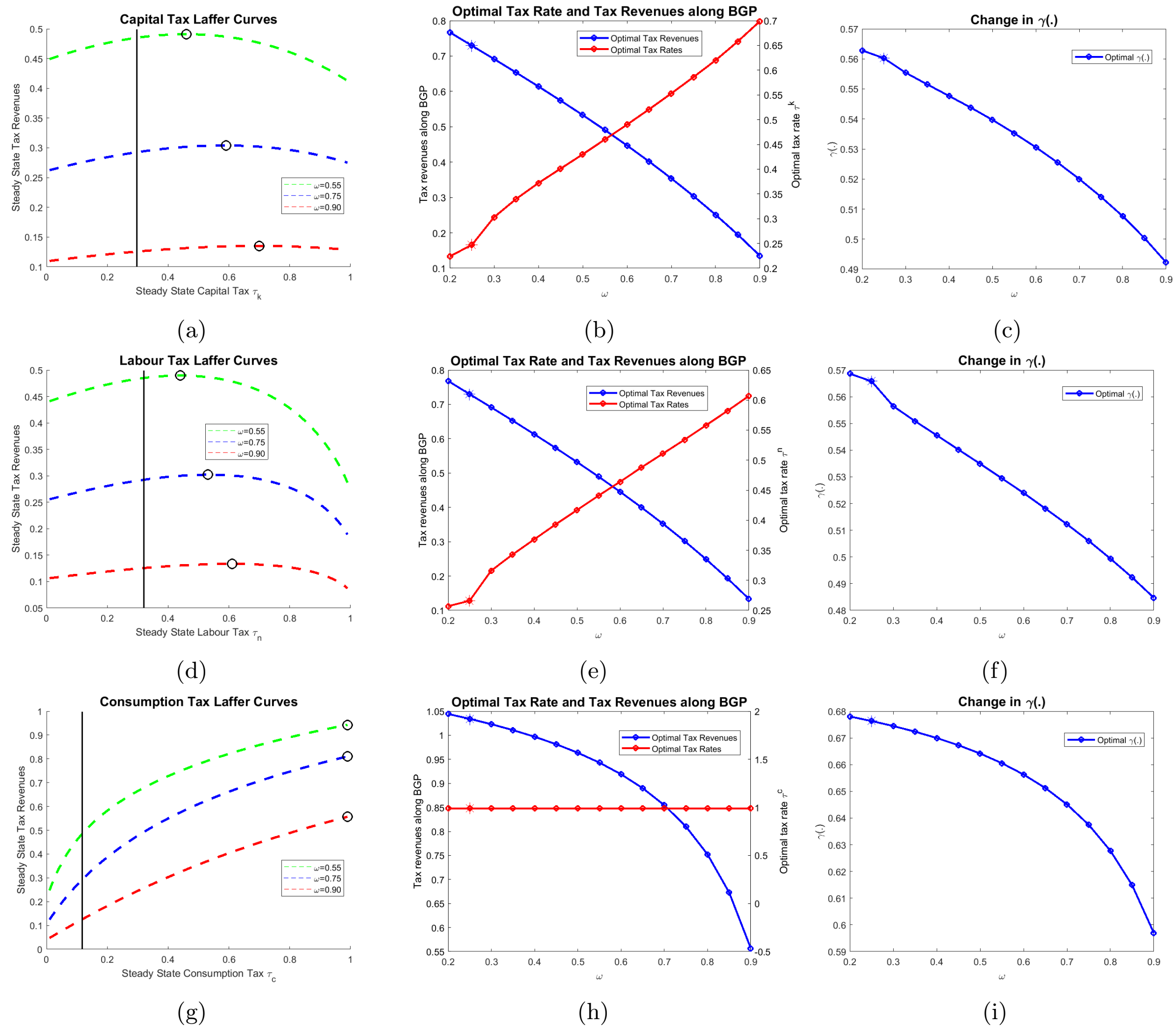


Figure 12: Effects of changes in ω, the share of non-Ricardian households

Table 7: Average Statutory tax rate, optimal tax rate, a percentage increase in tax revenues, and percentage self-financing of a tax cut. All values are expressed in percent.

	Share of non-Ricardian households, ω					
	90%		**75%**		**55%**	
	Capital	**Labour**	**Capital**	**Labour**	**Capital**	**Labour**
Average Statutory Tax Rate	29.68	32.04	29.68	32.04	29.68	32.04
Optimal Tax Rate	70	61	59	53	46	44
Percentage increase in tax revenue	-	-	125	126	61.5	62.06
Self-financing	17.87	29.27	40.72	49.75	67.33	73.63
Self-financing (Absence of tax-compliance channel)			26.66	26.10	57.96	57.01

Policy Implications

Table 8: Effect of a rise in probability of getting caught on tax revenue-to-GDP ratio (percent)

$\%\Delta\mu$	γ	$\%\Delta TR$	$\%\Delta(TR/y)$	$\overline{\gamma}$	$\%\Delta TR\|_{\overline{\gamma}}$	$\%\Delta(TR/y)\|_{\overline{\gamma}}$
1	57.50	3.65	2.29	53.90	1.25	0.83
3	62.23	8.68	5.41	53.90	3.75	2.47
5	65.53	12.34	7.65	53.90	6.24	4.08
8	69.38	16.58	10.22	53.90	9.97	6.41

Table 9: Welfare and distribution effect of a rise in consumption tax rates (percent)

$\%\Delta(\overline{\tau^c})$	$\%\Delta\overline{c^{rh}}$	$\%\Delta\overline{c^{re}}$	$\%\Delta\overline{c^{nr}}$	$\%\Delta\overline{n^{rh}}$	$\%\Delta\overline{n^{re}}$	$\%\Delta\overline{n^{nr}}$	$\%\Delta\overline{u^r}$	$\%\Delta\overline{u^{nr}}$	$\%\Delta\overline{u}$
1	-0.65	-1.07	-0.91	-1.49	-1.10	-0.85	0.13	-0.04	-0.03
3	-1.95	-3.13	-2.69	-4.32	-3.22	-2.52	0.25	-0.12	-0.10
5	-3.21	-5.10	-4.41	-6.95	-5.23	-4.13	0.23	-0.21	-0.19
10	-6.27	-9.63	-8.43	-12.80	-9.79	-7.93	-0.34	-0.47	-0.46

A. Technical Appendix

A.1. Optimality Conditions for Households

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

Ricardian-honest (rh) Households

Stage 1

$max_{c^{rh}_{r,t}, c^{rh}_{nr,t}} c^{rh}_t = [a_r^{\frac{1}{\epsilon_r}} (c^{rh}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1-a_r)^{\frac{1}{\epsilon_r}} (c^{rh}_{nr,t})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{\epsilon_r}{\epsilon_r - 1}},$
s. t. $p^r_t c^{rh}_{r,t} + p^{nr}_t c^{rh}_{nr,t} = M.$

The Lagrangian is given as, $L = c^{rh}_t + \lambda_t (M - p^r_t c^{rh}_{r,t} - p^{nr}_t c^{rh}_{nr,t}).$

Differentiating with respect to $c^{rh}_{r,t}$ and $c^{rh}_{nr,t}$, we get the following first order conditions,

$$\lambda_t p^r_t = a_r^{\frac{1}{\epsilon_r}} (c^{rh}_{r,t})^{\frac{-1}{\epsilon_r}} [a_r^{\frac{1}{\epsilon_r}} (c^{rh}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1-a_r)^{\frac{1}{\epsilon_r}} (c^{rh}_{nr,t})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{1}{\epsilon_r - 1}}, \tag{i}$$

$$\lambda_t p^{nr}_t = (1-a_r)^{\frac{1}{\epsilon_r}} (c^{rh}_{nr,t})^{\frac{-1}{\epsilon_r}} [a_r^{\frac{1}{\epsilon_r}} (c^{rh}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1-a_r)^{\frac{1}{\epsilon_r}} (c^{rh}_{nr,t})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{1}{\epsilon_r - 1}}. \tag{ii}$$

Dividing i by ii,

$$\frac{p^r_t}{p^{nr}_t} = (\frac{a_r}{1-a_r})^{\frac{1}{\epsilon_r}} (\frac{c^{rh}_{r,t}}{c^{rh}_{nr,t}})^{\frac{-1}{\epsilon_r}},$$

$$\implies c^{rh}_{nr,t} = (\frac{1-a_r}{a_r})(\frac{p_{nr}}{p_r})^{-\epsilon_r} c^{rh}_{r,t}. \tag{iii}$$

Using this into the objective function,

$$c^{rh}_t = [a_r^{\frac{1}{\epsilon_r}} (c^{rh}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1-a_r)^{\frac{1}{\epsilon_r}} [(\frac{1-a_r}{a_r})(\frac{p_{nr}}{p_r})^{-\epsilon_r} c^{rh}_{r,t}]^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{\epsilon_r}{\epsilon_r - 1}}.$$

Simplifying the above expression, we get,

$$c^{rh}_t = a_r^{-1} (p^r_t)^{\epsilon_r} c^{rh}_{r,t} [a_r (p^r_t)^{1-\epsilon_r} + (1-a_r)(p^{nr}_t)^{1-\epsilon_r}]^{\frac{-\epsilon_r}{1-\epsilon_r}}.$$

Let $P^r_t = [a_r (p^r_t)^{1-\epsilon_r} + (1-a_r)(p^{nr}_t)^{1-\epsilon_r}]^{\frac{1}{1-\epsilon_r}}$. Then,

$$c^{rh}_t = a_r^{-1} (p^r_t)^{\epsilon_r} c^{rh}_{r,t} (P^r_t)^{-\epsilon_r},$$

$$\implies c^{rh}_{r,t} = a_r (\frac{p^r_t}{P^r_t})^{-\epsilon_r} c^{rh}_t.$$

Substituting this into iii,

$$c_{nr,t}^{rh} = (1-a_r)(\frac{p_t^{nr}}{P_t^r})^{-\epsilon_r} c_t^{rh}.$$

Thus we have the final expressions for $c_{r,t}^{rh}$ and $c_{nr,t}^{rh}$,

$$c_{r,t}^{rh} = a_r(\frac{p_t^r}{P_t^r})^{-\epsilon_r} c_t^{rh} = a_r(T_t^r)^{-\epsilon_r} c_t^{rh},$$

$$c_{nr,t}^{rh} = (1-a_r)(\frac{p_t^{nr}}{P_t^r})^{-\epsilon_r} c_t^{rh} = (1-a_r)(T_t^{nr})^{-\epsilon_r} c_t^{rh},$$

where $P_t^r = [a_r(p_t^r)^{1-\epsilon_r} + (1-a_r)(p_t^{nr})^{1-\epsilon_r}]^{\frac{1}{1-\epsilon_r}}$ such that $P_t^r c_t^{rh} = p_t^r c_{r,t}^{rh} + p_t^{nr} c_{nr,t}^{rh}$. This implies $c_t^{rh} = T_t^r c_{r,t}^{rh} + T_t^{nr} c_{nr,t}^{rh}$, where T_t^r and T_t^{nr} represent price ratios.

Stage 2

Maximise utility function subject to budget constraint and capital accumulation equation.

Utility Function

$$u(c_t^{rh}, n_t^{rh}) = \frac{1}{1-\eta}((c_t^{rh})^{1-\eta}(1-\kappa^{rh}(1-\eta)(n_t^{rh})^{1+\frac{1}{\psi^r}})^{\eta} - 1).$$

Budget Constraint

$$(1+\tau_t^c)c_t^{rh} + x_t^{rh} + b_t^{rh} = (1-\tau_t^n)w_t^r n_t^{rh} + (1-\tau_t^k)(d_t-\delta)k_{t-1}^{rh} + \delta k_{t-1}^{rh} + R_t^b b_{t-1}^{rh} + s_t + \Pi_t^{rh}.$$

Capital Accumulation Equation

$$k_t^{rh} = (1-\delta)k_{t-1}^{rh} + x_t^{rh}.$$

First Order Conditions

The first order conditions with respect to $c_t^{rh}, n_t^{rh}, k_{t-1}^{rh}$ and b_t^{rh} are given by equations iv, v, vi and vii respectively,

$$\lambda_t^{rh} = \frac{u'_{c^{rh}}}{1+\tau_t^c}, \tag{iv}$$

$$\lambda_t^{rh} = \frac{-u'_{n^{rh}}}{(1-\tau_t^n)w_t^r}, \tag{v}$$

$$\lambda_t^{rh} = \beta^h \lambda_{t+1}^{rh}[1 + (1-\tau_{t+1}^k)(d_{t+1}-\delta)], \tag{vi}$$

$$R^b_{t+1} = \frac{\lambda^{rh}_t}{\beta^h \lambda^{rh}_{t+1}}. \tag{vii}$$

Dividing equation iv at time t by equation iv at time $(t+1)$ and using equation vii, we get the Euler's equation 7. Dividing equation iv by equation v, we get the labour supply equation 8. Lastly, using equation vii in equation vi, we get the first order condition for investment i.e. equation 9.

Ricardian-evading (re) Households

Stage 1

$max_{c^{re}_{r,t}, c^{re}_{nr,t}} c^{re}_t = [a_r^{\frac{1}{\epsilon_r}} (c^{re}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1 - a_r)^{\frac{1}{\epsilon_r}} (c^{re}_{nr,t})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{\epsilon_r}{\epsilon_r - 1}},$
s. t. $p^r_t c^{re}_{r,t} + p^{nr}_t c^{re}_{nr,t} = M.$

The Lagrangian is given as, $L = c^{re}_t + \lambda_t (M - p^r_t c^{re}_{r,t} - p^{nr}_t c^{re}_{nr,t})$.

Differentiating with respect to $c^{re}_{r,t}$ and $c^{re}_{nr,t}$, we get the following first order conditions,

$$\lambda_t p^r_t = a_r^{\frac{1}{\epsilon_r}} (c^{re}_{r,t})^{\frac{-1}{\epsilon_r}} [a_r^{\frac{1}{\epsilon_r}} (c^{re}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1 - a_r)^{\frac{1}{\epsilon_r}} (c^{re}_{nr,t})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{1}{\epsilon_r - 1}}, \tag{viii}$$

$$\lambda_t p^{nr}_t = (1 - a_r)^{\frac{1}{\epsilon_r}} (c^{re}_{nr,t})^{\frac{-1}{\epsilon_r}} [a_r^{\frac{1}{\epsilon_r}} (c^{re}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1 - a_r)^{\frac{1}{\epsilon_r}} (c^{re}_{nr,t})^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{1}{\epsilon_r - 1}}. \tag{ix}$$

Dividing viii by ix,

$$\frac{p^r_t}{p^{nr}_t} = (\frac{a_r}{1 - a_r})^{\frac{1}{\epsilon_r}} (\frac{c^{re}_{r,t}}{c^{re}_{nr,t}})^{\frac{-1}{\epsilon_r}},$$

$$\implies c^{re}_{nr,t} = (\frac{1 - a_r}{a_r})(\frac{p_{nr}}{p_r})^{-\epsilon_r} c^{re}_{r,t}. \tag{x}$$

Using this in the objective function,

$$c^{re}_t = [a_r^{\frac{1}{\epsilon_r}} (c^{re}_{r,t})^{\frac{\epsilon_r - 1}{\epsilon_r}} + (1 - a_r)^{\frac{1}{\epsilon_r}} [(\frac{1 - a_r}{a_r})(\frac{p_{nr}}{p_r})^{-\epsilon_r} c^{re}_{r,t}]^{\frac{\epsilon_r - 1}{\epsilon_r}}]^{\frac{\epsilon_r}{\epsilon_r - 1}}.$$

Simplifying the above expression, we get,

$$c^{re}_t = a_r^{-1} (p^r_t)^{\epsilon_r} c^{re}_{r,t} [a_r (p^r_t)^{1 - \epsilon_r} + (1 - a_r)(p^{nr}_t)^{1 - \epsilon_r}]^{\frac{-\epsilon_r}{1 - \epsilon_r}}.$$

P^r_t is defined as above in the Ricardian-honest household's problem. Thus,

$$c^{re}_t = a_r^{-1} (p^r_t)^{\epsilon_r} c^{re}_{r,t} (P^r_t)^{-\epsilon_r},$$

$$\implies c^{re}_{r,t} = a_r(\frac{p^r_t}{P^r_t})^{-\epsilon_r} c^{re}_t.$$

Substituting this into x, we get,

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

Thus we have the final expressions for $c^{re}_{r,t}$ and $c^{re}_{nr,t}$,

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

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

such that $P^r_t c^{re}_t = p^r_t c^{re}_{r,t} + p^{nr}_t c^{re}_{nr,t}$. This implies $c^{re}_t = T^r_t c^{re}_{r,t} + T^{nr}_t c^{re}_{nr,t}$.

Stage 2

Maximise utility function subject to budget constraint and capital accumulation equation.

Utility Function

$$u^i(c^{re}_t, n^{re}_t) = \frac{1}{1-\eta}((c^{re}_t)^{1-\eta}(1-\kappa^{re}(1-\eta)(n^{re}_t)^{1+\frac{1}{\psi^r}})^{\eta} - 1) - \mu\phi^r(i).$$

Budget Constraint

$$(1+\tau^c_t)c^{re}_t + x^{re}_t + b^{re}_t = [1-\tau^n_t\mu(1+\pi)]w^r_t n^{re}_t + [1-\tau^k_t\mu(1+\pi)](d_t-\delta)k^{re}_{t-1} + \delta k^{re}_{t-1} + R^b_t b^{re}_{t-1} + s_t + \Pi^{re}_t.$$

Capital Accumulation Equation

$$k^{re}_t = (1-\delta)k^{re}_{t-1} + x^{re}_t.$$

First Order Conditions

The first order conditions with respect to $c^{re}_t, n^{re}_t, k^{re}_{t-1}$ and b^{re}_t are given by equations xi, xii, xiii and xiv respectively,

$$\lambda^{re}_t = \frac{u'_{c^{re}}}{1+\tau^c_t}, \tag{xi}$$

$$\lambda^{re}_t = \frac{-u'_{n^{re}}}{[1-\tau^n_t\mu(1+\pi)]w^r_t}, \tag{xii}$$

$$\lambda^{re}_t = \beta^e \lambda^{re}_{t+1}[1 + [1-\tau^k_{t+1}\mu(1+\pi)](d_{t+1}-\delta)], \tag{xiii}$$

$$R^b_{t+1} = \frac{\lambda^{re}_t}{\beta^e \lambda^{re}_{t+1}}. \tag{xiv}$$

Dividing equation xi at time t by equation xi at time $(t+1)$ and using equation xiv, we get the Euler's equation 15. Dividing equation xi by equation xii, we get the labour supply equation 16. Lastly, using equation xiv in equation xiii, we get the first order condition for investment i.e. equation 17.

Non-Ricardian (nr) Households

Maximise utility function subject to budget constraint and capital accumulation equation.

Utility Function

$$u(c^{nr}_{nr,t}, n^{nr}_t) = \frac{1}{1-\eta}((c^{nr}_{nr,t})^{1-\eta}(1-\kappa^{nr}(1-\eta)(n^{nr}_t)^{1+\frac{1}{\psi^{nr}}})^{\eta} - 1).$$

Budget Constraint

$$(1+\tau^c_t)T^{nr}_t c^{nr}_{nr,t} = T^{nr}_t w^{nr}_t n^{nr}_t + s_t + T^{nr}_t \Pi^{nr}_t.$$

First Order Conditions

The first order conditions with respect to c^{nr}_t and n^{nr}_t are given by equations xv and xvi respectively,

$$\lambda^{nr}_t = \frac{u'_{c^{nr}_{nr}}}{(1+\tau^c_t)T^{nr}_t}, \tag{xv}$$

$$\lambda^{nr}_t = \frac{-u'_{n^{nr}}}{w^{nr}_t T^{nr}_t}. \tag{xvi}$$

Dividing equation xv by equation xvi, we get the labour supply equation 23.

A.2. Aggregation

Aggregating the budget constraints of the three types of households from equations 5, 13 and 22, with their respective mass, i.e., $(1-\omega)\gamma(.)$ for Ricardian-honest, $(1-\omega)(1-\gamma(.))$ for Ricardian-evader, and ω for non-Ricardian households, we obtain the following,

$$\begin{aligned}
(1-\omega)(1+\tau^c_t)[\gamma(.)c^{rh}_t + (1-\gamma(.))c^{re}_t] + (1-\omega)[\gamma(.)x^{rh}_t + (1-\gamma(.))x^{re}_t] + \\
(1-\omega)[\gamma(.)b^{rh}_t + (1-\gamma(.))b^{re}_t] + \omega(1+\tau^c_t)T^{nr}_t c^{nr}_{nr,t} \\
= (1-\omega)[w^r_t(\gamma(.)n^{rh}_t + (1-\gamma(.))n^{re}_t) + d_t(\gamma(.)k^{rh}_{t-1} + (1-\gamma(.))k^{re}_{t-1})] \\
- (1-\omega)[\tau^n_t w^r_t(\gamma(.)n^{rh}_t + (1-\gamma(.))\mu(1+\pi)n^{re}_t) + \tau^k_t(d_t-\delta)(\gamma(.)k^{rh}_{t-1} \\
+ (1-\gamma(.))\mu(1+\pi)k^{re}_{t-1})] + (1-\omega)R^b_t(\gamma(.)b^{rh}_{t-1} + (1-\gamma(.))b^{re}_{t-1}) \\
+ \omega T^{nr}_t w^{nr}_t n^{nr}_t + ((1-\omega)s_t + \omega s_t).
\end{aligned}$$

Aggregate economy-wide consumption is given by $c_t = (1-\omega)[\gamma(.)c_t^{rh} + (1-\gamma(.))c_t^{re}] + \omega T_t^{nr} c_{nr,t}^{nr}$, where,
$c_t^{rh} = T_t^r c_{r,t}^{rh} + T_t^{nr} c_{nr,t}^{rh}$,
$c_t^{re} = T_t^r c_{r,t}^{re} + T_t^{nr} c_{nr,t}^{re}$,
$x_t = \gamma(.)x_t^{rh} + (1-\gamma(.))x_t^{re}$,
$b_t = \gamma(.)b_t^{rh} + (1-\gamma(.))b_t^{re}$.

Aggregate economy-wide output is given by $y_t = (1-\omega)y_t^r + \omega T_t^{nr} y_t^{nr}$,
where $y_t^r = w_t^r n_t^r + d_t k_{t-1}^r$, $n_t^r = \gamma(.)n_t^{rh} + (1-\gamma(.))n_t^{re}$, $k_t = \gamma(.)k_t^{rh} + (1-\gamma(.))k_t^{re}$,
$y_t^{nr} = w_t^{nr} n_t^{nr}$.

Further, using government budget constraint equation 37,
$s_t = (1-\omega)(b_t - R_t^b b_{t-1}) + T_t - g_t$.

Using the above, we get,

$$c_t + (1-\omega)x_t + g_t = y_t.$$

A.3. Balanced Growth Path Equations

A.3.1. Ricardian-honest (rh) Households

Capital to Output Ratio

From equation 9, we have,

$$R_{t+1}^b = 1 + (1-\tau_{t+1}^k)(d_{t+1} - \delta).$$

Using equation 28,

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

we get,

$$\frac{R_{t+1}^b - 1}{1-\tau_{t+1}^k} = \theta \frac{y_{t+1}^r}{k_t^{rh}} - \delta \implies \frac{R_{t+1}^b - 1}{\theta(1-\tau_{t+1}^k)} + \frac{\delta}{\theta} = \frac{y_{t+1}^r}{k_t^{rh}}.$$

This gives equation 45 along the balanced growth path,

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

Consumption to Output Ratio

From equation 5,

$$(1+\tau_t^c)c_t^{rh} + x_t^{rh} + b_t^{rh} = (1-\tau_t^n)w_t^r n_t^{rh} + (1-\tau_t^k)(d_t - \delta)k_{t-1}^{rh} + \delta k_{t-1}^{rh} + R_t^b b_{t-1}^{rh} + s_t + \Pi_t^{rh}.$$

Using equation 6,

$$k_t^{rh} = (1-\delta)k_{t-1}^{rh} + x_t^{rh},$$

substituting for k_t^{rh} by $\zeta^r k_{t-1}^{rh}$, b_{t-1}^{rh} by $(\zeta^r)^t\overline{b}$, and using equations 28 and 29, we get,

$$(1+\tau_t^c)c_t^{rh}+(\zeta^r-1+\delta)k_{t-1}^{rh}+(\zeta^r)^{t+1}\overline{b} = (1-\tau_t^n)(1-\theta)y_t^r+(1-\tau_t^k)(\theta y_t^r-\delta k_{t-1}^{rh})+\delta k_{t-1}^{rh}+R_t^b(\zeta^r)^t\overline{b}+s_t.$$

Dividing throughout by y_t^r we get,

$$(1+\tau_t^c)\frac{c_t^{rh}}{y_t^r} = 1-(\zeta^r-1+\delta)\frac{k_{t-1}^{rh}}{y_t^r} + (R_t^b-\zeta^r)(\zeta^r)^t\overline{b}/y_t^r + s_t/y_t^r - [\tau_t^n(1-\theta)+\tau_t^k(\theta-\delta k_{t-1}^{rh}/y_t^r)].$$

Thus along the balanced growth path,

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

Labour Supply

From equation 8, we have,

$$\frac{u'_{c^{rh}}}{1+\tau_t^c} = \frac{-u'_{n^{rh}}}{(1-\tau_t^n)w_t^r},$$

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

Using equation 29,

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

we get,

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

Thus we get equation 48 along the balanced growth path,

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

where $\overline{\alpha^{rh}} = \frac{(1+\overline{\tau^c})(1+\frac{1}{\psi})}{(1-\overline{\tau^n})(1-\theta)}$.

A.3.2. Ricardian-evading (re) Households

Capital to Output Ratio

From equation 17, we have,

$$R_{t+1}^b = 1+[1-\tau_{t+1}^k\mu(1+\pi)](d_{t+1}-\delta).$$

Using equation 28,

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

we get,

$$\frac{R_{t+1}^b - 1}{1 - \tau_{t+1}^k \mu(1+\pi)} = \theta \frac{y_{t+1}^r}{k_t^{re}} - \delta \implies \frac{R_{t+1}^b - 1}{\theta[1 - \tau_{t+1}^k \mu(1+\pi)]} + \frac{\delta}{\theta} = \frac{y_{t+1}^r}{k_t^{re}}.$$

This gives equation 52 along the balanced growth path,

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

Consumption to Output Ratio

From equation 13,

$$(1+\tau_t^c)c_t^{re} + x_t^{re} + b_t^{re} = [1-\tau_t^n \mu(1+\pi)]w_t^r n_t^{re} + [1-\tau_t^k \mu(1+\pi)](d_t - \delta)k_{t-1}^{re} + \delta k_{t-1}^{re} + R_t^b b_{t-1}^{re} + s_t + \Pi_t^{re}.$$

Using equation 14,

$$k_t^{re} = (1-\delta)k_{t-1}^{re} + x_t^{re},$$

substituting for k_t^{re} by $\zeta^r k_{t-1}^{re}$, b_{t-1}^{re} by $(\zeta^r)^t \overline{b}$, and using equations 28 and 29, we get,

$$\begin{aligned}(1+\tau_t^c)c_t^{re} + (\zeta^r - 1 + \delta)k_{t-1}^{re} + (\zeta^r)^{t+1}\overline{b} =& [1 - \tau_t^n \mu(1+\pi)](1-\theta)y_t^r + [1 - \tau_t^k \mu(1+\pi)](\theta y_t^r - \delta k_{t-1}^{re}) \\ &+ \delta k_{t-1}^{re} + R_t^b (\zeta^r)^t \overline{b} + s_t.\end{aligned}$$

Dividing throughout by y_t^r we get,

$$(1+\tau_t^c)\frac{c_t^{re}}{y_t^r} = 1 - (\zeta^r - 1 + \delta)\frac{k_{t-1}^{re}}{y_t^r} + (R_t^b - \zeta^r)(\zeta^r)^t \overline{b}/y_t^r + s_t/y_t^r - \mu(1+\pi)[\tau_t^n(1-\theta) + \tau_t^k(\theta - \delta k_{t-1}^{re}/y_t^r)].$$

Thus we get equation 57 along the balanced growth path,

$$\begin{aligned}\overline{c^{re}/y^r} = \frac{1}{(1+\overline{\tau^c})}\{&1 - (\zeta^r - 1 + \delta)\overline{k^{re}/y^r} + \overline{s/y}\overline{y}/\overline{y^r} + (\overline{R^b} - \zeta^r)\overline{b/y}\overline{y}/\overline{y^r} \\ &- \mu(1+\pi)[\overline{\tau^n}(1-\theta) + \overline{\tau^k}(\theta - \delta\overline{k^{re}/y^r})]\}.\end{aligned}$$

Labour Supply

From equation 16, we have,

$$\frac{u'_{c^{re}}}{1+\tau_t^c} = \frac{-u'_{n^{re}}}{(1-\tau_t^n \mu(1+\pi))w_t^r},$$

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

Using equation 29,

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

we get,

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

Thus we get equation 55 along the balanced growth path,

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

where $\overline{\alpha^{re}} = \frac{(1+\overline{\tau^c})(1+\frac{1}{\psi^r})}{(1-\overline{\tau^n}\mu(1+\pi))(1-\theta)}$.

A.3.3. Non-Ricardian (nr) Households

Consumption to Output Ratio

From equation 22,

$$(1+\tau_t^c)T_t^{nr}c_{nr,t}^{nr} = T_t^{nr}w_t^{nr}n_t^{nr} + s_t + T_t^{nr}\Pi_t^{nr}.$$

Using equation 31,

$$w_t^{nr} = \frac{y_t^{nr}}{n_t^{nr}},$$

we get,

$$(1+\tau_t^c)T_t^{nr}c_{nr,t}^{nr} = T_t^{nr}y_t^{nr} + s_t.$$

Dividing through by $y_t^{nr}T_t^{nr}$,

$$(1+\tau_t^c)\frac{c_{nr,t}^{nr}}{y_t^{nr}} = 1 + s_t/(y_t^{nr}T_t^{nr}).$$

Thus we get equation 59 along the balanced growth path,

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

Labour Supply

From equation 23, we have,

$$\frac{u'_{c_{nr}^{nr}}}{1+\tau_t^c} = \frac{-u'_{n^{nr}}}{w_t^{nr}},$$

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

Using equation 31,

$$n_t^{nr} = \frac{y_t^{nr}}{w_t^{nr}},$$

we get,

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

Thus we get equation 58 along the balanced growth path,

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

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

A.4. Laffer Curve

From the tax revenue equation 38,

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

where $c_t^{rh} = T_t^r c_{r,t}^{rh} + T_t^{nr} c_{nr,t}^{rh}$ and $c_t^{re} = T_t^r c_{r,t}^{re} + T_t^{nr} c_{nr,t}^{re}$.

Using first-order conditions of Ricardian firms, and dividing throughout by y, we get equation 61,

$$\begin{aligned} L = \overline{T/y} =& \overline{\tau^c}\{\omega\overline{T^{nr}}\overline{c_{nr}^{nr}/y^{nr}}.\overline{y^{nr}/n^{nr}}.\overline{n^{nr}} + (1-\omega)[\gamma(.)\overline{c^{rh}/y^r}.\overline{y^r/n^r}.\overline{n^r} + (1-\gamma(.))\overline{c^{re}/y^r}.\overline{y^r/n^r}.\overline{n^r}]\} \\ &+ (1-\omega)\{\overline{\tau^n}[\gamma(.)(1-\theta)\overline{y^r}/\overline{y} + (1-\gamma(.))\mu(1+\pi)(1-\theta)\overline{y^r}/\overline{y}] \\ &+ \tau^k[\gamma(.)(\theta - \delta\overline{k^{rh}/y^r})\overline{y^r}/\overline{y} + (1-\gamma(.))\mu(1+\pi)(\theta - \delta\overline{k^{re}/y^r})\overline{y^r}/\overline{y}]\}. \end{aligned}$$

A.5. Proof of Propositions 1 and 2

A.5.1. Proposition 1

Proof. Along the balanced growth path, from equations 44 and 51, we have,

$$k_t^{rh}/y_t^r = [\frac{R_t^b - 1}{\theta(1-\tau_t^k)} + \frac{\delta}{\theta}]^{-1},$$

and

$$k_t^{re}/y_t^r = [\frac{R_t^b - 1}{\theta(1-\tau_t^k\mu(1+\pi))} + \frac{\delta}{\theta}]^{-1}.$$

$k_t^{re}/y_t^r > 0 \iff \tau_t^k < \frac{1}{\mu(1+\pi)}$. Further, when $0 \leq \mu(1+\pi) < 1$, $k_t^{re}/y_t^r > k_t^{rh}/y_t^r$, thus $k_t^{re} > k_t^{rh}$.

Further, from equations 49 and 56, we have,

$$(1+\tau_t^c)\frac{c_t^{rh}}{y_t^r} = 1 - (\zeta^r - 1 + \delta)\frac{k_{t-1}^{rh}}{y_t^r} + (R_t^b - \zeta^r)(\zeta^r)^t\overline{b}/y_t^r + s_t/y_t^r - [\tau_t^n(1-\theta) + \tau_t^k(\theta - \delta k_{t-1}^{rh}/y_t^r)],$$

and

$$(1+\tau_t^c)\frac{c_t^{re}}{y_t^r} = 1-(\zeta^r-1+\delta)\frac{k_{t-1}^{re}}{y_t^r}+(R_t^b-\zeta^r)(\zeta^r)^t\bar{b}/y_t^r+s_t/y_t^r-\mu(1+\pi)[\tau_t^n(1-\theta)+\tau_t^k(\theta-\delta k_{t-1}^{re}/y_t^r)].$$

This gives us $\frac{c_t^{re}}{y_t^r} - \frac{c_t^{rh}}{y_t^r}$ as,

$$\frac{c_t^{re}}{y_t^r} - \frac{c_t^{rh}}{y_t^r} = \frac{1}{(1+\tau_t^c)}\{[1-\mu(1+\pi)]\tau_t^n(1-\theta) - (\zeta^r-1+\delta)[\frac{k_{t-1}^{re}}{y_t^r} - \frac{k_{t-1}^{rh}}{y_t^r}] + \tau_t^k(\theta-\delta k_{t-1}^{rh}/y_t^r) - \mu(1+\pi)\tau_t^k(\theta-\delta k_{t-1}^{re}/y_t^r)\}. \tag{xvii}$$

The first term on the right-hand side, $[1-\mu(1+\pi)]\tau_t^n(1-\theta) > 0 \;\forall\; 0 \le \mu(1+\pi) < 1$.

The second term can be simplified as follows,

$$\begin{aligned}(\zeta^r-1+\delta)[\frac{k_{t-1}^{re}}{y_t^r} - \frac{k_{t-1}^{rh}}{y_t^r}] &= (\zeta^r-1+\delta)\{[\frac{R_t^b-1}{\theta(1-\tau_t^k\mu(1+\pi))}+\frac{\delta}{\theta}]^{-1} - [\frac{R_t^b-1}{\theta(1-\tau_t^k)}+\frac{\delta}{\theta}]^{-1}\}\\ &= (\zeta^r-1+\delta)\theta\{\frac{(1-\tau_t^k\mu(1+\pi))}{R_t^b-1+\delta(1-\tau_t^k\mu(1+\pi))} - \frac{(1-\tau_t^k)}{R_t^b-1+\delta(1-\tau_t^k)}\}.\end{aligned}$$

After some simple algebra, this expression can be rewritten as,

$$(\zeta^r-1+\delta)[\frac{k_{t-1}^{re}}{y_t^r} - \frac{k_{t-1}^{rh}}{y_t^r}] = \frac{\theta\tau_t^k(R_t^b-1)(1-\mu(1+\pi))}{[R_t^b-1+\delta(1-\tau_t^k)][R_t^b-1+\delta(1-\tau_t^k\mu(1+\pi))]}(\zeta^r-1+\delta). \tag{xviii}$$

Further, we simplify the third term in equation xvii as follows,

$$\begin{aligned}&\tau_t^k[(\theta-\delta k_{t-1}^{rh}/y_t^r)-\mu(1+\pi)(\theta-\delta k_{t-1}^{re}/y_t^r)]\\ &\quad= \tau_t^k[(\theta-\delta[\frac{R_t^b-1}{\theta(1-\tau_t^k)}+\frac{\delta}{\theta}]^{-1}) - \mu(1+\pi)(\theta-\delta[\frac{R_t^b-1}{\theta(1-\tau_t^k\mu(1+\pi))}+\frac{\delta}{\theta}]^{-1}]\\ &\quad= \tau_t^k\theta[\frac{(R_t^b-1)}{(R_t^b-1+\delta(1-\tau_t^k))} - \mu(1+\pi)\frac{(R_t^b-1)}{(R_t^b-1+\delta(1-\tau_t^k\mu(1+\pi)))}].\end{aligned}$$

This can be simplified to,

$$\begin{aligned}&\tau_t^k[(\theta-\delta k_{t-1}^{rh}/y_t^r)-\mu(1+\pi)(\theta-\delta k_{t-1}^{re}/y_t^r)]\\ &\quad= \frac{\theta\tau_t^k(R_t^b-1)(1-\mu(1+\pi))}{[R_t^b-1+\delta(1-\tau_t^k)][R_t^b-1+\delta(1-\tau_t^k\mu(1+\pi))]}(R_t^b-1+\delta).\end{aligned} \tag{xix}$$

Using xviii and xix we have,

$$\tau_t^k[(\theta - \delta k_{t-1}^{rh}/y_t^r) - \mu(1+\pi)(\theta - \delta k_{t-1}^{re}/y_t^r)] - (\zeta^r - 1 + \delta)[\frac{k_{t-1}^{re}}{y_t^r} - \frac{k_{t-1}^{rh}}{y_t^r}] \\ = \frac{\theta\tau_t^k(R_t^b - 1)(1-\mu(1+\pi))}{[R_t^b - 1 + \delta(1-\tau_t^k)][R_t^b - 1 + \delta(1-\tau_t^k\mu(1+\pi))]}(R_t^b - \zeta^r). \tag{xx}$$

Along the balanced growth path, we have $R_t^b = \frac{(\zeta^r)^\eta}{\beta}$, where $\beta \in (0,1)$ is the discount factor, $\zeta^r > 1$ is the growth rate of the Ricardian sector and $\eta > 1$ is the inverse of the intertemporal elasticity of consumption. Thus, $R_t^b > \zeta^r$ and xx is positive given our assumptions, i.e. $0 \leq \mu(1+\pi) < 1$ and $\tau_t^k < \frac{1}{\mu(1+\pi)}$.

Thus, xvii is positive. This implies $\frac{c_t^{re}}{y_t^r} - \frac{c_t^{rh}}{y_t^r} > 0$ or $c_t^{re} > c_t^{rh}$ when $0 \leq \mu(1+\pi) < 1$.

Now, we look at labour supply. From equations 47 and 54 we have,

$$n_t^{rh} = [\kappa^{rh}(\eta\alpha_t^{rh}c_t^{rh}/y_t^r - \eta + 1)]^{\frac{-\psi^r}{1+\psi^r}}, \tag{xxi}$$

where $\alpha_t^{rh} = \frac{(1+\tau_t^c)(1+\frac{1}{\psi^r})}{(1-\tau_t^n)(1-\theta)}$,

and

$$n_t^{re} = [\kappa^{re}(\eta\alpha_t^{re}c_t^{re}/y_t^r - \eta + 1)]^{\frac{-\psi^r}{1+\psi^r}}, \tag{xxii}$$

where $\alpha_t^{re} = \frac{(1+\tau_t^c)(1+\frac{1}{\psi^r})}{(1-\tau_t^n\mu(1+\pi))(1-\theta)}$.

We observe that when $\mu(1+\pi) < 1$, $c_t^{re} > c_t^{rh}$ but $\alpha_t^{re} < \alpha_t^{rh}$. Moreover, in our calibrations $\kappa^{re} > \kappa^{rh}$ when $\mu(1+\pi) < 1$. Therefore, it is unclear whether $n_t^{re} \gtrless n_t^{rh}$.

If $n_t^{rh} > n_t^{re}$, we have $u(c_t^{re}, n_t^{re})_{partial} > u(c_t^{rh}, n_t^{rh})$ since $u'_{c,t} > 0$ and $u'_{n,t} < 0$.

However, if $n_t^{rh} < n_t^{re}$, dividing equation 8 by equation 16, we have,

$$\frac{u'_{n_t^{re}}}{u'_{c_t^{re}}}\frac{u'_{c_t^{rh}}}{u'_{n_t^{rh}}} = \frac{(1-\tau_t^n\mu(1+\pi))}{(1-\tau_t^n)}, \tag{xxiii}$$

where $u'_c > 0, u'_n < 0, u''_c < 0, u''_n < 0$. The term on the right-hand side of xxiii is greater than 1 when $\mu(1+\pi) < 1$. Further, $c_t^{re} > c_t^{rh} \implies \frac{u'_{c_t^{rh}}}{u'_{c_t^{re}}} > 1$. Moreover, $n_t^{re} > n_t^{rh} \implies \frac{u'_{n_t^{re}}}{u'_{n_t^{rh}}} > 1$. However, the expression on the right-hand side, $\frac{(1-\tau_t^n\mu(1+\pi))}{(1-\tau_t^n)}$, puts a limit on the value that the left-hand side can take. Given this, the household cannot choose n_t^{re} that is much higher than n_t^{rh}. Thus, the household would choose n_t^{rh} and n_t^{re} such that xxiii holds and $u(c_t^{re}, n_t^{re})_{partial} > u(c_t^{rh}, n_t^{rh})$.

Here $u(c_t^{re}, n_t^{re})_{partial} = \frac{1}{1-\eta}(c_t^{re})^{1-\eta}(1 - \kappa^{re}(1-\eta)(n_t^{re})^{1+\frac{1}{\psi^r}})^{\eta} - 1)$ and
$u(c_t^{rh}, n_t^{rh}) = \frac{1}{1-\eta}(c_t^{rh})^{1-\eta}(1 - \kappa^{rh}(1-\eta)(n_t^{rh})^{1+\frac{1}{\psi^r}})^{\eta} - 1)$.

The rest of the proof follows directly from equation 20 and Lemma 1. □

A.5.2. Proposition 2

Proof. The proof for Proposition 2 is similar to that for Proposition 1, so we will skip the details here.

When $\mu(1+\pi) = 1$, from equations 44 and 51, $k_t^{rh} = k_t^{re}$. From xvii, this implies $c_t^{rh} = c_t^{re}$. Further, $\alpha_t^{rh} = \alpha_t^{re}$, and κ^{rh} and κ^{re} are calibrated such that they are equal when $\mu(1+\pi) = 1$. Thus, from xxi and xxii we have $n_t^{rh} = n_t^{re}$. This implies $u(c_t^{re}, n_t^{re})_{partial} = u(c_t^{rh}, n_t^{rh})$. Further proof follows from equation 20 and Lemma 1.

When $\mu(1+\pi) > 1$, from equations 44 and 51, $k_t^{re} < k_t^{rh}$. From xvii, this implies $c_t^{re} < c_t^{rh}$. However, from equations 47 and 54, when $\mu(1+\pi) > 1$, $c_t^{re} < c_t^{rh}$ but $\alpha_t^{re} > \alpha_t^{rh}$. Moreover, in our calibrations $\kappa^{re} < \kappa^{rh}$ when $\mu(1+\pi) > 1$. Therefore, it is unclear whether $n_t^{re} \gtreqless n_t^{rh}$. If $n_t^{rh} < n_t^{re}$, we have $u(c_t^{re}, n_t^{re})_{partial} < u(c_t^{rh}, n_t^{rh})$ since $u'_{c,t} > 0$ and $u'_{n,t} < 0$. If however $n_t^{rh} > n_t^{re}$, the term on the right-hand side of xxiii is less than 1 when $\mu(1+\pi) > 1$. Given this, the household would choose n_t^{rh} and n_t^{re} such that $u(c_t^{re}, n_t^{re})_{partial} < u(c_t^{rh}, n_t^{rh})$.

The rest of the proof follows directly from equation 20 and Lemma 1. □

B. Data Appendix

B.1. Data Collected from World Bank

We have collected data for 195 countries out of which 40 are Advanced Economies (AEs) and 155 are Emerging Market and Developing Economies (EMDEs), as per division by IMF.[63] We have collected data on Control of Corruption, Government Effectiveness and Tax revenue as a percentage of GDP from World Bank (2024d) and Hours taken to file taxes from World Bank (2024a). The data was accessed on 21st July, 2023. We provide details regarding the datasets below.

Control of Corruption: The data for Control of Corruption indicator has been collected from the World Development Indicators database of World Bank. According to the website, "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 gives the country's score on the aggregate indicator, in units of a stan-

[63]The categorisation of countries by IMF can be found here: Groups and Aggregates

dard normal distribution, i.e. ranging from approximately -2.5 to 2.5."

Government Effectiveness: The data for Government Effectiveness indicator has been collected from the World Development Indicators database of World Bank. According to the website, "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 gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5."

Tax Revenue as a percentage of GDP: The data for Tax Revenue as a percentage of GDP has been collected from the World Development Indicators database of World Bank. According to the website, "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: The data for hours taken to file taxes in a year has been collected from the Doing Business database of World Bank. According to the website, it is "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 labour taxes, including payroll taxes and social contributions."

Further, the list of countries for which we have the data is as follows,

Emerging Market and Developing Economies (EMDEs): Afghanistan; Albania; Algeria; Angola; Antigua and Barbuda; Argentina; Armenia; Aruba; Azerbaijan; Bahamas, The; Bahrain; Bangladesh; Barbados; Belarus; Belize; Benin; Bhutan; Bolivia; Bosnia and Herzegovina; Botswana; Brazil; Brunei Darussalam; Bulgaria; Burkina Faso; Burundi; Cabo Verde; Cambodia; Cameroon; Central African Republic; Chad; Chile; China; Colombia; Comoros; Congo, Dem. Rep.; Congo, Rep.; Costa Rica; Cote dâIvoire; Djibouti; Dominica; Dominican Republic; Ecuador; Egypt, Arab Rep.; El Salvador; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; Fiji; Gabon; Gambia, The; Georgia; Ghana; Grenada; Guatemala; Guinea; Guinea-Bissau; Guyana; Haiti; Honduras; Hungary; India; Indonesia; Iran, Islamic Rep.; Iraq; Jamaica; Jordan; Kazakhstan; Kenya; Kiribati; Kosovo; Kuwait; Kyrgyz Republic; Lao PDR; Lebanon; Lesotho; Liberia; Libya; Madagascar; Malawi; Malaysia; Maldives; Mali; Marshall Islands; Mauritania; Mauritius; Mexico; Micronesia, Fed. Sts.; Moldova; Mongolia; Montenegro; Morocco; Mozambique; Myanmar; Namibia; Nauru; Nepal; Nicaragua; Niger; Nigeria; North Macedonia; Oman; Pakistan; Palau; Panama; Papua New Guinea; Paraguay; Peru; Philippines; Poland; Qatar; Romania; Russian Federation; Rwanda;

Samoa; Sao Tome and Principe; Saudi Arabia; Senegal; Serbia; Seychelles; Sierra Leone; Solomon Islands; Somalia; South Africa; South Sudan; Sri Lanka; St. Kitts and Nevis; St. Lucia; St. Vincent and the Grenadines; Sudan; Suriname; Syrian Arab Republic; Tajikistan; Tanzania; Thailand; Timor-Leste; Togo; Tonga; Trinidad and Tobago; Tunisia; Turkiye; Turkmenistan; Tuvalu; Uganda; Ukraine; United Arab Emirates; Uruguay; Uzbekistan; Vanuatu; Venezuela, RB; Viet Nam; West Bank and Gaza; Yemen, Rep.; Zambia; Zimbabwe

Advanced Economies (AEs): Andorra; Australia; Austria; Belgium; Canada; Croatia; Cyprus; Czechia; Denmark; Estonia; Finland; France; Germany; Greece; Hong Kong SAR, China; Iceland; Ireland; Israel; Italy; Japan; Korea, Dem. Peoples Rep.; Latvia; Lithuania; Luxembourg; Macao SAR, China; Malta; Netherlands; New Zealand; Norway; Portugal; Puerto Rico; San Marino; Singapore; Slovak Republic; Slovenia; Spain; Sweden; Switzerland; United Kingdom; United States

B.2. Details of Calibrations

We calibrate the model to data for India, Indonesia, the Philippines, Sri Lanka and Vietnam for the time period 2005-2019. The data was accessed between 21-29 September, 2024.

We take data for average annual hours worked by persons engaged for India, from Feenstra et al. (2015). We divide the value by $(365 * 14)$ to obtain the fraction of a day spent by an individual engaged in labour, considering that an individual has 14 hours to allocate between labour and leisure, using the methodology followed by Trabandt and Uhlig (2011).

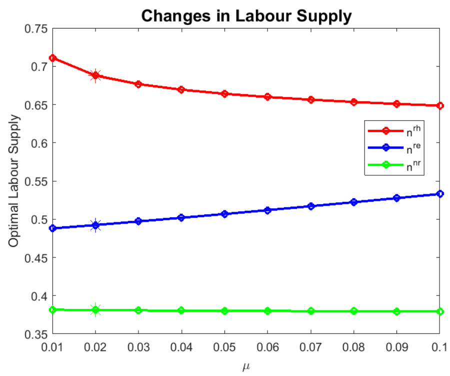
Government transfers as a share of total expenditure is available with IMF (2024). Further, government expenditure as a share of GDP is available with World Bank (2024d). We have used these to construct an estimate of government transfers as a share of GDP, by multiplying the two ratios.

To calculate the growth rate for the non-Ricardian sector, we use the DGE model-based estimates of informal output as a percentage of GDP provided in the Elgin et al. (2021a). We multiply these values by official GDP estimates from Feenstra et al. (2015) to obtain estimates for informal sector GDP.

C. Further Results

C.1. Comparative Statics

C.1.1. Probability of Getting Caught: μ



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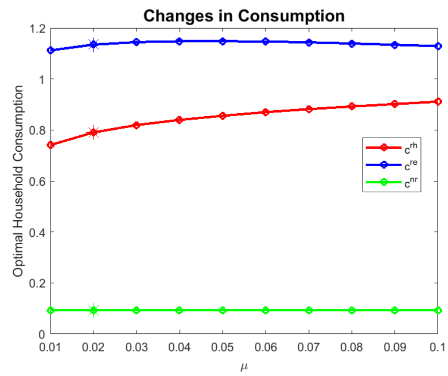

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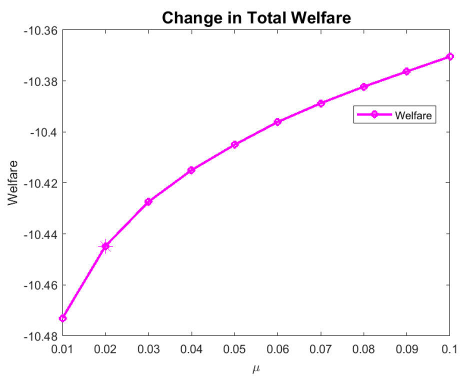
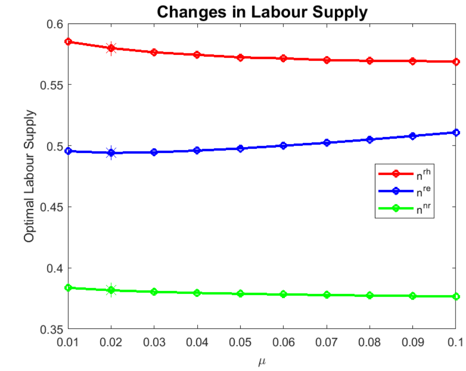


(c)

Figure C.1: Effects of changes in μ as tax on capital is optimised



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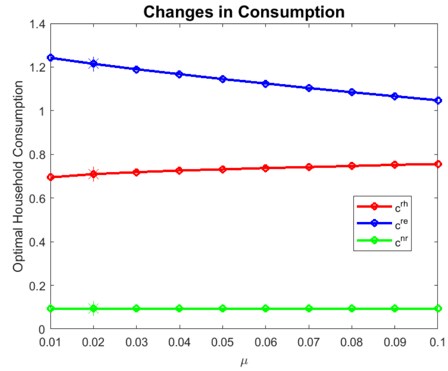

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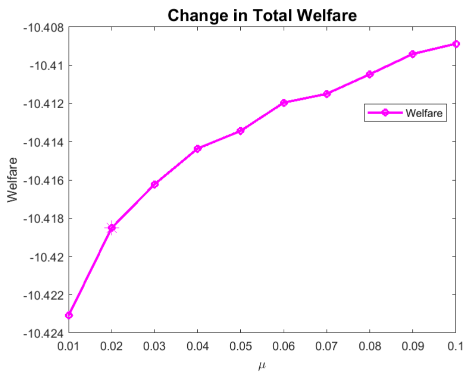

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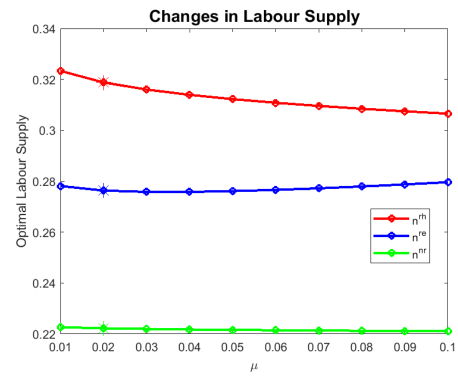
Figure C.2: Effects of changes in μ as tax on labour is optimised



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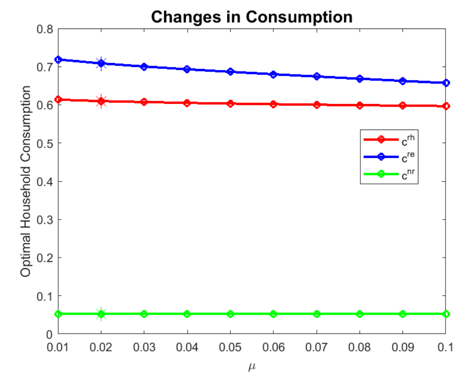

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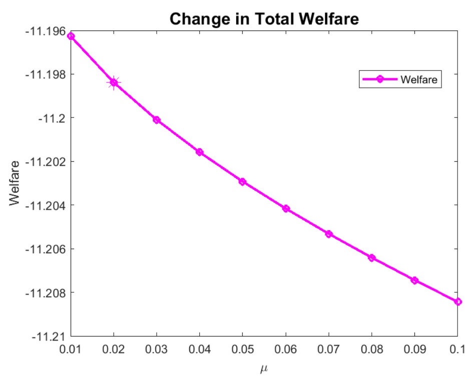

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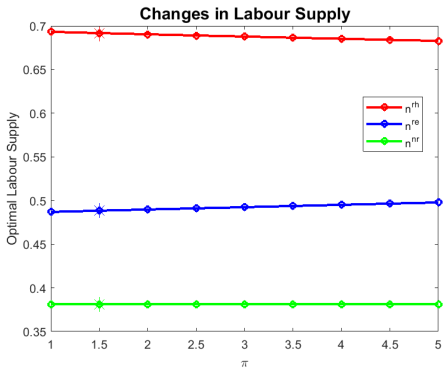
Figure C.3: Effects of changes in μ as tax on consumption is optimised

C.1.2. Penalty on Getting Caught: π



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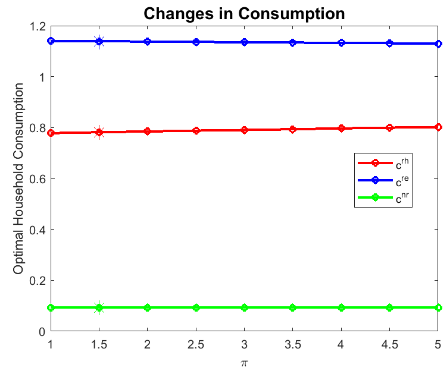

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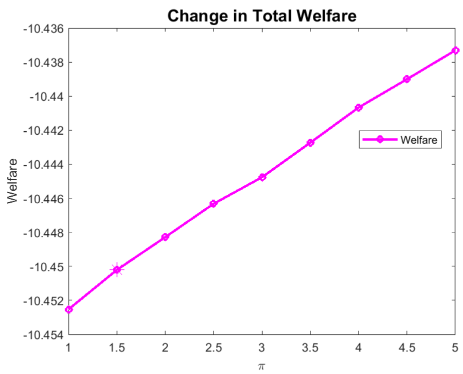

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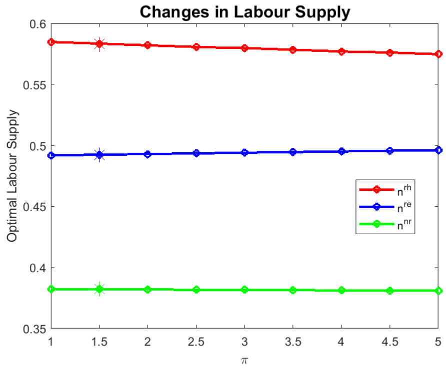
Figure C.4: Effects of changes in π as tax on capital is optimised



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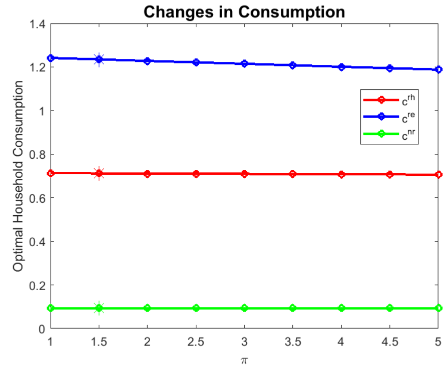

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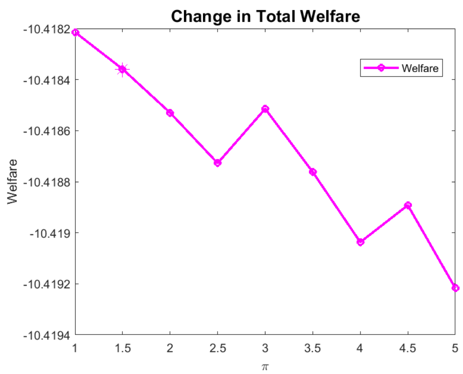

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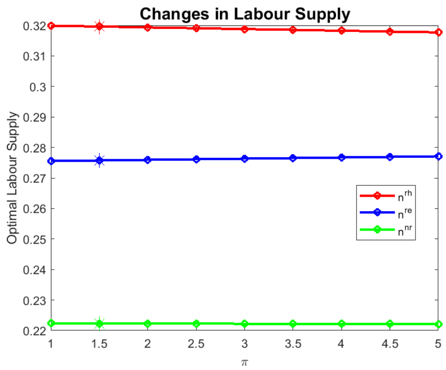
Figure C.5: Effects of changes in π as tax on labour is optimised



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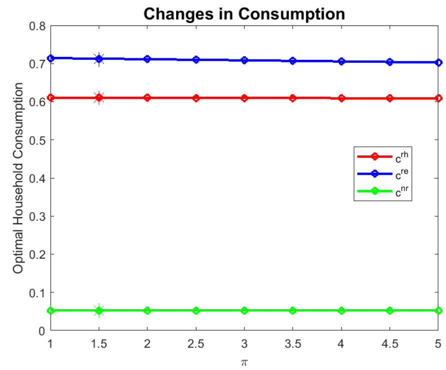

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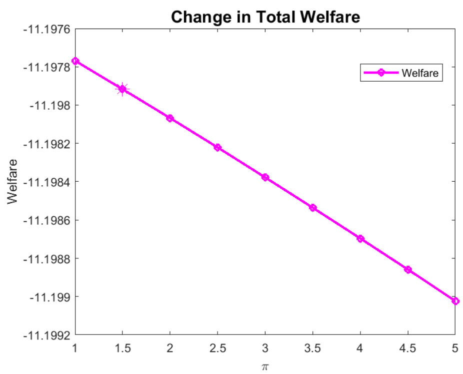

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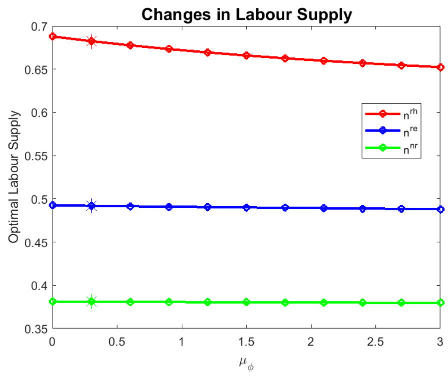
Figure C.6: Effects of changes in π as tax on consumption is optimised

C.1.3. Mean of Disutility Parameter: μ_ϕ



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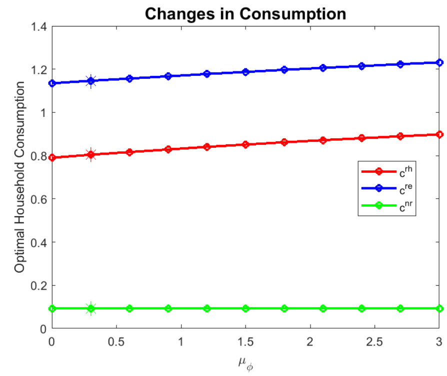

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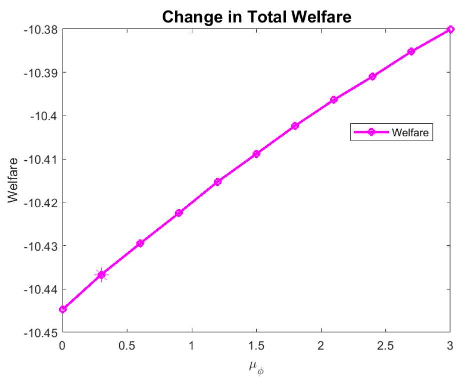

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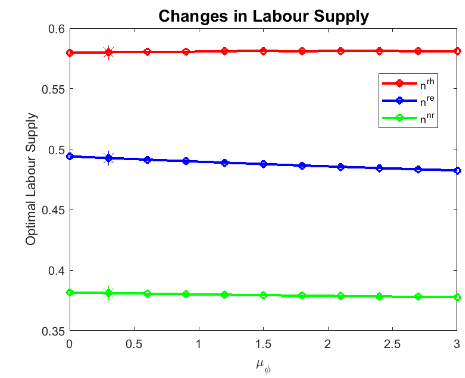
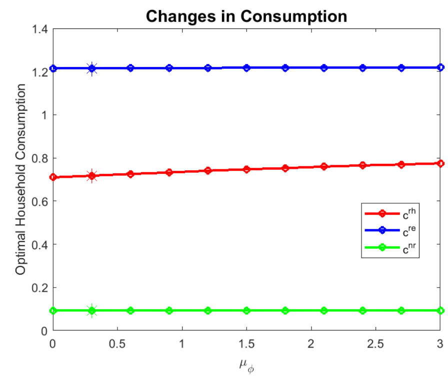
Figure C.7: Effects of changes in μ_ϕ as tax on capital is optimised



(a)



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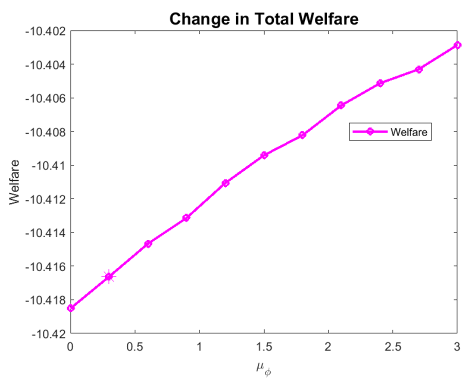
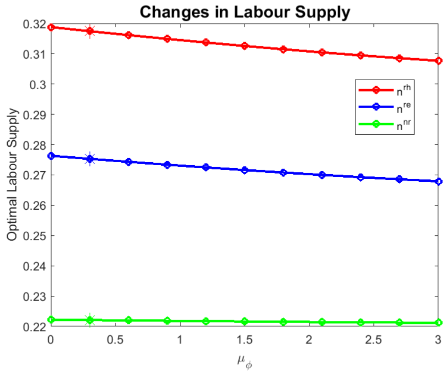
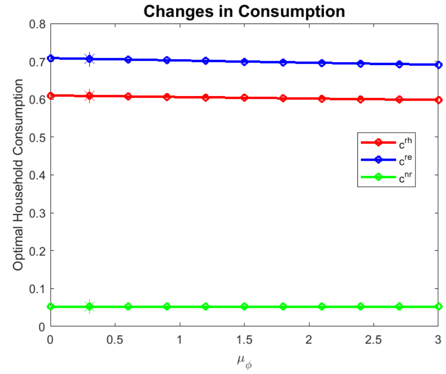


(c)

Figure C.8: Effects of changes in μ_ϕ as tax on labour is optimised



(a)



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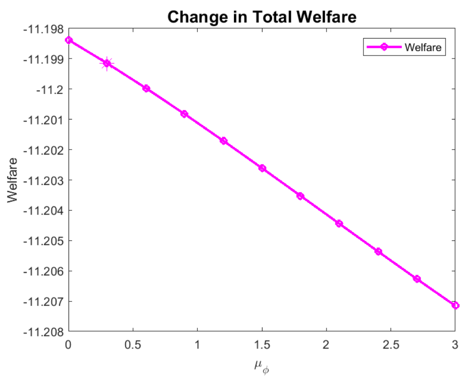
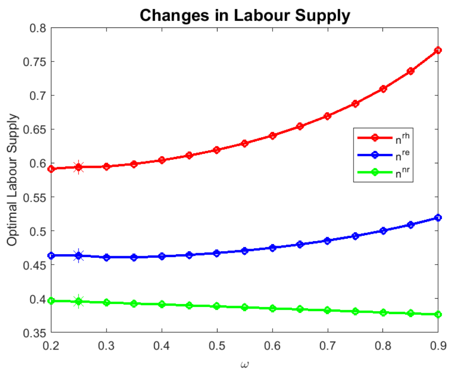


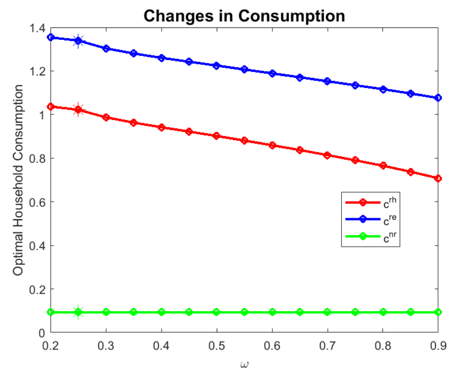
(c)

Figure C.9: Effects of changes in μ_ϕ as tax on consumption is optimised

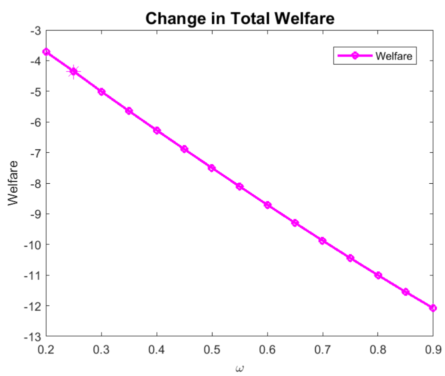
C.1.4. Proportion of Non-Ricardian Households in the Economy: ω



(a)



(b)



(c)

Figure C.10: Effects of changes in ω as tax on capital is optimised

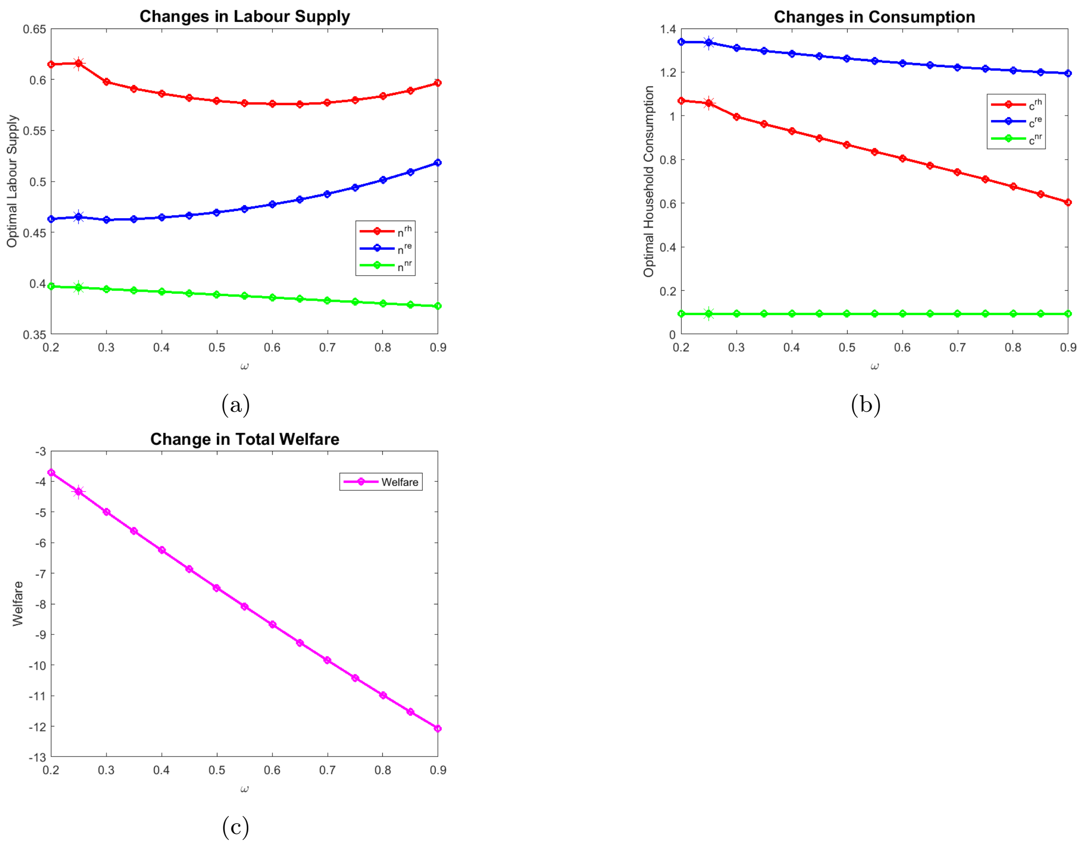


Figure C.11: Effects of changes in ω as tax on labour is optimised

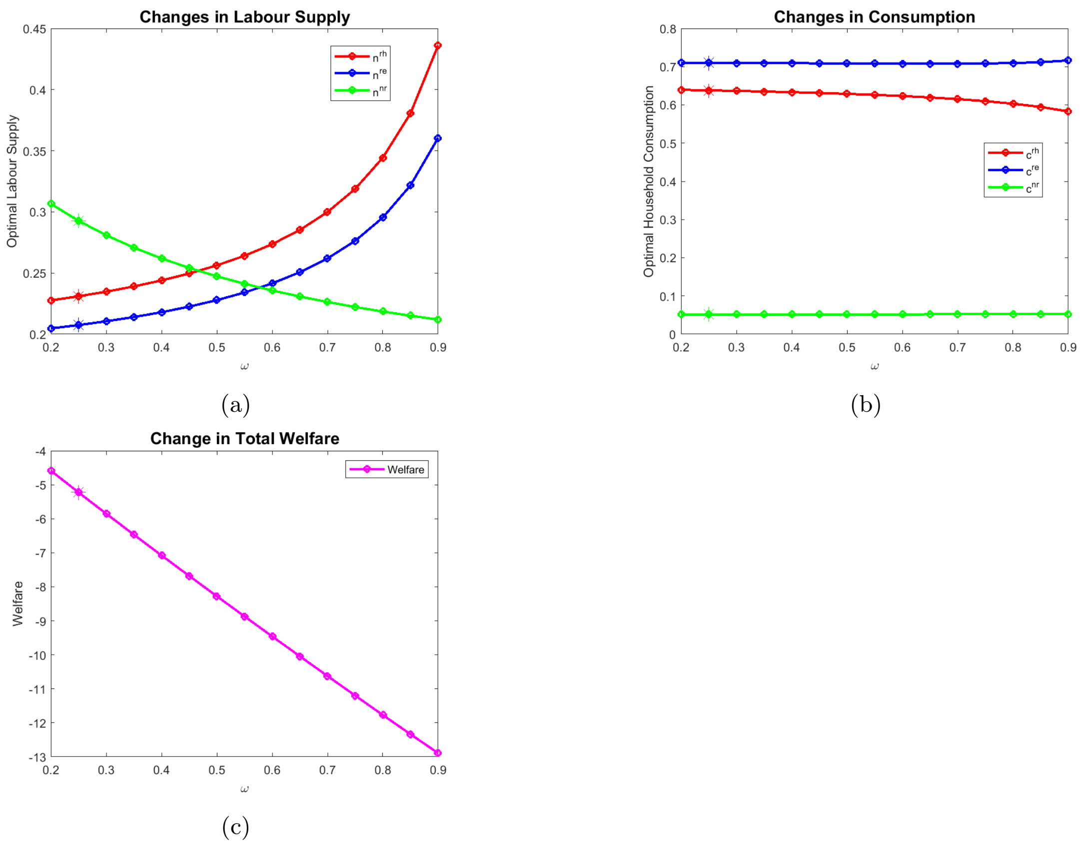


Figure C.12: Effects of changes in ω as tax on consumption is optimised