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Fernando Moraes Carneiro

Essays in Macroeconomics: Public Debt Reform, Progressive Taxation and Distributional Effects of Fiscal Policy

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Tese apresentada como requisito parcial para obtenção do título de Doutor, ao Programa de Pós-graduação em Ciências Econômicas, da Universidade do Estado do Rio de Janeiro. Área de Concentração: Economia Aplicada

Orientador: Prof.º Dr. Octavio Augusto Fontes Tourinho

Coorientador: Prof.º Dr. Stephen J. Turnovsky

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Fernando Moraes Carneiro

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Banca Examinadora:

Octavio AF Tourinho

Prof. Dr. Octavio Augusto Fontes Tourinho (Orientador)
Faculdade de Ciências Econômicas – UERJ

Prof. Dr. Stephen J. Turnovsky (Coorientador)
Department of Economics – University of Washington

Prof. Dr. Elcyon Caiado Rocha Lima
Faculdade de Ciências Econômicas – UERJ

ABCunha

Prof. Dr. Alexandre Barros Cunha
Instituto de Economia – UFRJ

Prof. Dr. Wilfredo Fernando Leiva Maldonado
Faculdade de Economia, Administração, Contabilidade e Atuária – USP

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DEDICATION

To my children, Felipe and Julia, and my wife, Leticia.

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ABSTRACT

CARNEIRO, Fernando Moraes. *Essays in Macroeconomics*: Public Debt Reform, Progressive Taxation and Distributional Effects of Fiscal Policy. 2023. 138 f. Tese (Doutorado em Ciências Econômicas) – Faculdade de Ciências Econômicas, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, 2023.

This thesis is composed of three chapters devoted to study the effects of macroeconomic fiscal policies on economic growth and the distribution of income. The first chapter addresses the chronic fiscal imbalance of the Brazilian economy, which became more acute because of the fiscal efforts adopted to countervail the recessionary effects of the subprime crisis of 2008, the 2014-16 recession and, more recently, the COVID-19 pandemic. The study employs a dynamic general equilibrium model that distinguishes economic agents by their decision horizon and access to financial markets, and explores the dynamic effects of changes in fiscal mix and public debt consolidation strategies. The two types of households – Ricardians and non-Ricardians – correspond roughly to different income classes and the quantitative analysis assess the effects of these reforms on macroeconomic variables and welfare, leading to the conclusion that the distributive conflicts contribute to the lack of agreement with respect to the implementation of fiscal adjustments, and that this is a consequence of rational behavior of heterogeneous households. While the study targets the Brazilian economy, it can be also extended to other developing countries that experience similar fiscal challenges. Following, the second and the third chapters develop versions of an endogenous growth model with a progressive tax structure to investigate the tradeoff between economic growth and inequality. They are set up as dynamic general equilibrium models, and assume that the agents' heterogeneity arises from differences in the intertemporal elasticity of substitution, rather than differences in the discount rate which is more often encountered in the literature. They show that the long-term equilibrium distributions of income and wealth are not degenerate, and that households that have higher willingness to substitute future for present consumption end up owning the largest fraction of the capital stock. In the second chapter, the model is calibrated to reflect a typical OECD country and considers a household disaggregation based on income quintiles, while the numerical simulations depict two complementary scenarios that evaluate the effects of tax reforms that eliminates the progressivity of the labor income tax but retains the progressivity of the capital income tax. The results show that increasing the progressivity of the tax on capital income reduces inequality faster and further than just eliminating progressivity on labor income without changing the tax on capital, although this effect comes at the expense of economic growth. The third chapter develops a version of the model where the tax code does not distinguish the sources of income, and the progressive tax is on total income, which is used to assess the effects of a reform that mimics the Tax Cuts and Jobs Act of 2017. The results reveal that such tax cut, which is financed by reducing the government consumption, boosts economic activity in the short run and sustain this growth during the transition, although lead to a slight increase in long-run inequality.

Keywords: Fiscal Policy. Public Debt. Dynamic General Equilibrium. non-Ricardian Households. Progressive Taxation. Growth Models. Inequality.

RESUMO

CARNEIRO, Fernando Moraes. *Ensaios em Macroeconomia*: Reforma da Dívida Pública, Tributação Progressiva e Efeitos Distributivos da Política Fiscal. 2023. 138 f. Tese (Doutorado em Ciências Econômicas) – Faculdade de Ciências Econômicas, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, 2023.

Esta tese compreende três artigos dedicados à análise de políticas fiscais macroeconômicas sob o ponto de vista do crescimento econômico e a distribuição de renda. O primeiro capítulo aborda o desequilíbrio fiscal crônico da economia brasileira, que se agravou diante dos efeitos recessivos da crise do *subprime* em 2008, a recessão entre 2014 e 2016 e, mais recentemente, da pandemia da COVID-19. O estudo emprega um modelo de equilíbrio geral dinâmico que distingue os agentes econômicos quanto ao horizonte temporal de decisão e ao acesso ao mercado financeiro, e explora os efeitos dinâmicos de diferentes estratégias de *mix* fiscal e de consolidação da dívida pública. Os dois tipos de agentes – Ricardianos e não-Ricardianos – correspondem a diferentes classes de renda e a análise quantitativa apresenta os efeitos das reformas sobre as variáveis macroeconômicas e o bem-estar, levando à conclusão de que os conflitos distributivos contribuem para a falta de acordo quanto à implementação de ajustes fiscais, e que isto é uma consequência do comportamento racional dos agentes heterogêneos. O estudo tem como alvo a economia brasileira, mas pode ser estendido a outros países em desenvolvimento que enfrentem desafios fiscais similares. O segundo e o terceiro capítulos, por sua vez, desenvolvem versões de um modelo de crescimento endógeno com uma estrutura tributária progressiva para investigar o *tradeoff* entre crescimento econômico e desigualdade. Eles são estabelecidos como modelos dinâmicos de equilíbrio geral, e assumem que a heterogeneidade dos agentes surge de diferenças na elasticidade intertemporal de substituição, ao invés de na taxa de desconto, como é mais comumente encontrado na literatura. Os capítulos mostram que a economia converge no longo-prazo para uma distribuição não-degenerada de renda e riqueza em que os agentes mais dispostos a substituir o consumo ao longo do tempo detêm a maior fração do estoque de capital. No segundo capítulo, o modelo é calibrado para refletir um país típico da OCDE e considera uma desagregação das famílias com base em quintis de renda, enquanto as simulações numéricas retratam dois cenários complementares que avaliam os efeitos de reformas que eliminam a progressividade do imposto de renda do trabalho, mas mantém a progressividade do imposto de renda do capital. Os resultados mostram que tornar o imposto sobre a renda do capital mais progressivo reduz a desigualdade mais rápida e profundamente do que apenas eliminar a progressividade sobre a renda do trabalho sem alterar o imposto sobre a renda do capital, embora este efeito ocorra em detrimento do crescimento econômico. O terceiro capítulo desenvolve uma versão do modelo em que tributação não distingue as fontes de renda e o imposto progressivo incide sobre a renda total, e é aplicado para avaliar os efeitos de uma reforma que imita o *Tax Cuts and Jobs Act* de 2017. Os resultados revelam que esse corte de impostos financiado pela redução do consumo do governo impulsiona a atividade econômica no curto prazo e sustenta esse crescimento durante a transição, embora leve a um sutil aumento da desigualdade no longo-prazo.

Palavras-chave: Política Fiscal. Dívida Pública. Equilíbrio Geral Dinâmico. Modelos de Crescimento. Indivíduos não-Ricardianos. Taxação Progressiva. Desigualdade.

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INTRODUCTION

The global economy suffered in this century successive crises that have affected economic activity through many channels. First, the 2008 global subprime crisis exposed vulnerabilities in the financial market and resulted in a credit crunch that damaged private investment and led to dramatic output losses (Keeley and Love, 2010). More recently, the spread of the Covid-19 has affected factor productivity in unprecedented ways and has plunged the global economy into a deep recession (IMF, 2020). Further, the distributional effects sparked by the pandemic have been severe, especially in emerging markets and low-income countries due to their large portion of vulnerable individuals as well as the obstacles faced by the policymakers to implement sound containment policies (World Bank, 2020).

Irrespective of the nature of these shocks, the response of many governments around the world was to adopt aggressive countercyclical fiscal measures to recover economic activity. However, the sharp increase in public expenditures led to a serious undermining of the fiscal position in several economies and raised the discussion about the sustainability of fiscal policy, renewing the interest of economists in the analysis of macroeconomic effects of fiscal reforms aimed at consolidating public debt (Papageorgiou, 2012; Corsetti et al., 2013; Tourinho and Brum, 2020). Moreover, a crucial aspect of the debate, especially in developing countries has been how to implement fiscal reforms without deepening the economic inequality (Agnello and Sousa, 2012; IMF, 2014; Alesina, Favero and Giavazzi, 2019). This thesis aims to extend the literature by assessing some of these compelling macroeconomic issues and comprises three essays that explore the effects of fiscal reforms in an economy characterized by heterogeneous agents.

The first essay builds a dynamic general equilibrium model with two household types distinguished by their access to the financial market and their marginal productivity of labor, and aims to assess the dynamic effects of fiscal reforms and debt stabilization policies. The calibration of the model reflects the key features of the Brazilian economy around 2016. The main issue addressed is how the difference of the welfare effects across households of a given fiscal reform can be a source of the impasse regarding its adoption. The analysis and conclusion apply to Brazil, but can be extrapolated to several other developing economies. In addition, the study advocates the importance of considering the heterogeneity of economic agents in general equilibrium models, because it offers a more accurate picture of the effects of the adoption of fiscal austerity programs on inequality and growth, and its social cost in the short and medium term.

The first essay follows the strand of literature that adopts a neoclassical growth model setup, bearing in mind the empirical evidence in Caselli, Esquivel and Lefort (1996) that rejects the absence of conditional convergence in a broad panel of countries. The remaining chapters, instead, employ an endogenous growth model framework due to its ability to address issues concerned with long-run growth and its suitability for analysis by casting capital accumulation in a broader concept – an amalgam of human and physical capital (Romer, 1994; Turnovsky, 2000) and allowing constant returns to it.

Indeed, chapters 2 and 3 explore the long-run tradeoff between economic growth and inequality by evaluating the effects of fiscal policies on the long-run growth rate and mapping more precisely the transitional dynamics to the new steady-state in a model economy with progressive taxation and agents with different willingness to substitute future for present consumption. The second essay evaluates the effects of a generic policy designed to reduce inequality and provides a keen insight into the recent discussion of a differentiated marginal tax rate on wealth for top income percentiles. The calibration of the model reflects a typical OECD economy, and considers a household disaggregation based on income quintiles. It assesses the effects of a tax reform that eliminates the progressivity of the tax on labor income while maintaining, or increasing, the progressivity of the tax on capital income. The third essay, in turn, extends the model to explore the distributive effects of a tax cut financed by a decrease in public consumption. The model parameterization reflects the US economy, also considers a household disaggregation based on income quintiles and simulates a tax reform that reduces the tax burden by changing the level of the tax schedule, in the spirit of 2017's USA Tax Cuts and Jobs Act (TCJA). The discussion highlights the dynamic effects of that policy on the Income GINI index and the growth rate, and traces implications for the growth–income inequality tradeoff.

Finally, it is worth mentioning that these three essays were accepted, and included in the program of several academic meetings over the last three years, and have benefited from comments received in them. The essay in the first chapter was presented in three academic meetings in 2019: the North American Summer Meeting of the Econometric Society in Seattle, U.S.A, the European Summer Meeting of Econometric Society in Manchester, U.K., and the 47º Encontro Nacional de Economia of Associação Nacional de Programas de Pos-Graduação em Economia (ANPEC) in São Paulo, Brazil. In 2020, the essay in the second chapter was presented in 42nd Meeting of Sociedade Brasileira de Econometria, held virtually. The essay in the third chapter was presented in the 2021 Latin American Meeting of the Econometric Society (LAMES) hosted virtually by Universidad del Rosario, Bogotá, Colombia. An extended version of that essay was presented in the 2022 North American Summer Meeting of the Econometric Society in Miami, U.S.A., and in the 2022 International Conference on Public Economic Theory in Marseille, France. The Journal of Economic Dynamics and Control has recently published an extended version of the third essay, which has the advisor and coadvisor of this thesis as coauthors.

1 FISCAL POLICY FOR PUBLIC DEBT STABILIZATION IN A MULTIPLE HOUSEHOLD DYNAMIC GENERAL EQUILIBRIUM MODEL FOR BRAZIL

1.1 Introduction

Fiscal policy in many countries has faced several new challenges in the last 20 years. Public debt has increased significantly in several cases because of fiscal permissiveness in financing the increasing cost and breadth of social security, expansion and creation of social programs, development of large infrastructure projects, and of subsidies and tax forfeiture.[1] The rate of public debt accumulation has also increased due to the need to finance the expansionary policies used in many countries to countervail the recessionary effects of the subprime crisis of 2008 and, more recently, the COVID-19 pandemic. The financing of the interest cost of public debt by issuing more debt has also magnified the process, by reinforcing the original structural imbalance and, in some cases, producing an explosive trajectory of the public debt. Irrespective of its origin, the control of indebtedness has required the adoption of fiscal austerity programs that have a high social cost in the short and medium term that made their unpopular, ultimately resulting in a controversial atmosphere for its political acceptance. The need for instruments to prospectively assess the effectiveness, sustainability, and economic impact of these programs, and justify their adoption, has led to the development of models to assist in their design and evaluation.[2] The present study contributes to that effort, with special reference to Brazil.

The Brazilian fiscal problem is chronic (Giambiagi and Além, 2016), and has become more acute after 2014, when very large primary deficits occurred as a result of large increases in public expenditure and some decreases in net tax revenue. The main factors responsible for the recession that lasted from 2014 to 2016, which was the country's second largest after the World War II [3] were, according Barbosa Filho (2017), the fiscal policies used to address the resulting explosive debt accumulation and the political instability associated with the impeachment of the President in August of 2016. Although the declines in real GDP ceased in December 2016, the economy did not recover, and GDP growth was only 1.3%, 1.8% and 1.2%

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[1] Examples of countries with previous fiscal imbalances are Greece, Ireland, Portugal and Spain.

[2] For a survey on the effects of fiscal policy on growth see, for example, Zagler and Dürnecker (2003).

[3] The three worst recessions in postwar Brazil were (GDP declines in parenthesis): 1981-83 (-8.5%), 1989-92 (-7.7%) and 2014-2016 (-8.2%) according to CODACE (2017).

in 2017, 2018 and 2019, respectively.[4] These facts, and the high real interest rate that prevailed in the country until the end of 2017, have led to very large increases in the relative size of the total gross public debt, from 55.5% of GDP in 2006 to 77.3% of GDP at the end of 2018. Some fiscal adjustment policies implemented during 2019 were unable to reverse that trend, and the gross public debt reached 77.7% of GDP at the end of 2019.[5] Furthermore, the fiscal policies adopted during the coronavirus pandemic further aggravated the situation and made the total gross public debt reach 90.1% of GDP at the end of 2020 (see IFI (2021)).

There is ample empirical evidence of the deleterious effects of large public debts on economic growth, as forcefully pointed out by Reinhart and Rogoff (2010, 2011) and confirmed in a voluminous subsequent literature, reviewed in Panizza and Presbitero (2013) and Tourinho and Sangoi (2017), for example. In particular, Alesina et al. (2015) examined empirically the effects of debt stabilization plans on growth and find that adjustments based on spending cuts induces negligible output costs when compared with adjustments that increase the tax burden, highlighting that private investment plays a key role in mitigating the recessionary effects of fiscal consolidations. However, these empirical models, while useful to formulate policies to restore fiscal balance and stabilize the public debt, are not sufficient to design such plans because they do not fully handle the complex linkages implied by the intertemporal nature of the problem. Applied dynamic general equilibrium models that include a detailed account of the government budget, its financing, and public debt can better consider them and, for this reason, are the tool of choice in the literature for that purpose.

The model presented here is an extension of Papageorgiou (2012) that discusses public debt consolidation alternatives for Greece in the usual representative agent framework, in order to consider the existence of two types of households, distinguished by their access to the financial markets. One household type is able to borrow and lend and can smooth consumption, while the other does not, and is constrained to consume current income. The model proposed here inherits most of its the other features from the model. In short, it is a Ramsey-Cass-Koopmans (RCK) infinite horizon exogenous growth model on which it is based a neoclassical aggregate production function that displays decreasing returns to factors (labor, human capital and public capital),[6] augmented with public spending which may be productive or unproductive

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[4] In 2020, the coronavirus (COVID-19) pandemic and the health measures adopted to contain its spread produced loss of 3.8%, which the GDP growth of 4.6% in 2021 recovered by.

[5] See IFI (2020).

[6] This choice of technology contrasts with the AK technology of Romer (1986) used in endogenous growth models (Rebelo, 1990), that have been adapted to analyze fiscal policy. The use of an exogenous growth model is

(Aschauer, 1989). Consumers are characterized by a CRRA (Constant Relative Risk Aversion) utility function that displays non-unitary elasticity of intertemporal substitution, contemplates endogenous labor supply, and admits the substitution between private and government consumption. Its workings is similar to that in Baxter and King (1993),[7] where an increase of current public debt finances a reduction of the tax burden, but this requires future compensatory measures to maintain the Government's intertemporal budget in balance.

To address the main fiscal policy choices Papageorgiou (2012) considers a wide spectrum of tax and spending instruments, as in Barro and Sala-i-Martin (1993, 2004) and Turnovsky and Fischer (1995). However, he adds to those earlier studies the possibility of occurrence of deficits, and of financing them by the issuance of public debt as, for example, in Brock and Turnovsky (1981).[8] The policies he considers are changes in the tax-spending mix, and changes in a single fiscal instrument to first reduce, and then stabilize the public debt at this lower level. He finds that best policy to boost long run output is an increase of government investment accompanied by a compensating decrease in transfers, and that to favor welfare it is the reduction of government consumption accompanied by a reduction in capital income tax. He also finds that best single instrument to reduce the public debt by 10% and stabilize it at the lower level is, from the point of view of output, based on the labor and capital income tax rates. From the point of view of the welfare index, the best single instrument for consolidating the public debt is government investment.

Tourinho and Brum (2020) calibrated the Papageorgiou (2012) model for Brazil, and used it to study public debt consolidation by performing simulation exercises similar to the ones summarized above, but reach different conclusions regarding the ranking of the fiscal policies, mostly because they normalize the simulations to correspond to a fiscal effort of 1% of GDP. [9] They find that the best fiscal mix change to increase long-run output (by about 2%) is the reduction of government consumption associated with a decrease of the capital income tax rate. They also find that to reduce the public debt by 10% and stabilize it at the lower level the best single instrument is the capital income tax rate if the subsidiary objective is the long-term

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consistent with the empirical evidence in Caselli, Esquivel and Lefort (1996) that rejects the absence of conditional convergence in a broad panel of countries.

[7] Note, however, that Baxter and King (1993) is an endogenous growth model.

[8] See also Turnovsky (2000, chapter 9). Note, however, that Papageorgiou (2012) does not include money and the inflation tax in his model.

[9] Because of the difference in normalization, the fiscal mix change simulations in Tourinho and Brum (2020) are not directly comparable to those in Papageorgiou (2012). Section 3 of this chapter also discusses this further.

increase in consumption and of the welfare index, and it is government investment, if the subsidiary objective is the long-run output.

However, considering that these policies increase welfare, it is puzzling that in Greece and Brazil they did do not gather widespread political support when they were proposed. This phenomenon also possibly occurred in many other countries. This suggests that the model outlined above does not capture some important aspect of the broader macroeconomic problem. One of the insights of this chapter is to argue that the missing feature is household heterogeneity, especially with respect to the access to financial markets.[10] To assess if this is the case for Brazil, and how it can affect the policy conclusions extracted from the model, this chapter extends the formulation of that model to consider that feature, and uses the resulting model to perform the same policy simulations as in those found in Tourinho and Brum (2020). The comparison of the results of the original and the extended model indicates that it is important to consider household heterogeneity in designing fiscal policies for public debt stabilization because the desirability of a given debt consolidation program may be quite different for them, and the ensuing disagreement may lead to a impasse about its adoption.

The extended model formulated here provides insights on the formulation of fiscal policy for the Brazilian economy, but its application is broader, since the existence of a significant fraction of agents that are "rule-of-thumb" households is a stylized feature of developing countries. These agents decide consumption based mostly on current income rather than intertemporal utility maximization, as indicated by Mankiw and Campbell (1990) and Galí et al. (2004, 2007). The reason for the existence for such structural difference is not an object of analysis here, but Mankiw (2000) and others have suggested that this type of heterogeneity may be due to credit constraints and, following his proposed terminology, these two household types are denominated *non-Ricardian* and *Ricardian*, respectively.[11,12] It is also important to emphasize that the extension proposed here is part of a broader effort to increase the use of

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[10] One can point out that the lack of political agreement with respect to the design of public debt consolidation policies observed is a phenomenon influenced by several factors, such as political ideology of the congress' majority, historical social movements, institutional organization, etc. Although it is clear that other factors play a role in this debate, the focus here is to show that this lack of political support can arises when the rational behavior of heterogeneous households leads to different responses to debt-stabilization plans, thus affecting the distribution of welfare effects.

[11] Marto (2014) presents an alternative formulation that also gives rise to this dual typology of households, based on a "catching up with Joneses" preference structure for the Ricardian households, while the non-Ricardian households have the usual preferences. Employing a New Keynesian stochastic model, he estimates the proportion of rule-of-thumb consumers to the Portuguese economy and calibrates their proportion. He also claims that considering heterogeneity it is of crucial importance.

[12] Log-linearized DSGE models often use this approach in the study fluctuations in the neighborhood of a given steady state, but it is not well suited to study the trajectory between steady states, as is done here.

formulations that consider the heterogeneity of economic agents in macroeconomic models, as advocated by Vines and Wills (2018).

The Ricardian households take the interest rate in consideration when making consumption and investment decision, but the non-Ricardian households do not. If the share of non-Ricardian consumers is large, this difference in behavior will alter in a significant manner the effect of interest rates on the real side of the economy, and its response to fiscal and monetary policies.[13] Further, to the extent that these two types of households correspond roughly to different income classes, this conflict over fiscal policy becomes a reflection of a distributive conflict that is present in Brazil, and seems to occur also in several other developing economies also.

Several other studies in the literature have examined the effects of household heterogeneity and of income inequality on fiscal policy, but most do not emphasize their implication for public debt consolidation. García-Peñalosa and Turnovsky (2011) build upon Turnovsky (1996, 1997) and study the impact of changes in taxation on the dynamics of wealth and income distribution in a neoclassical growth model with endogenous labor supply, and go beyond earlier studies by assuming that it is subject to a negative wealth effect.[14] They find strong evidence of the existence of a trade-off between output growth and inequality, and warn against increasing the labor income tax rate to finance an increase in public transfers to households because this reduces labor supply and output, and accentuates inequality. They recommend financing it by increasing the consumption tax rate because this produces a smaller decrease in the level of output, and is effective in reducing income inequality. This is relevant in the context of this study because the impact of the stabilization program on income inequality is an indication of its social acceptability, which certainly influences decisions in the political arena.

The model specified here is a deterministic DGE that yields the perfect forecast solution of the corresponding stochastic model (DSGE). The marginal conditions for the optimum comprise a system of non-linear equations that we solve numerically to obtain the dynamic trajectory of the economy, as it moves from the calibrated initial steady state to another post-

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[13] Gomes (2013) claims there are robust indications that current income plays a fundamental role in determining consumption in the Brazilian economy, and that this is due to the presence of consumers that face credit restrictions that hinder their ability to smooth consumption.

[14] This means that marginal utility of wealth is a decreasing function of wealth, thus wealthier agents choose to increase consumption of all goods, which includes leisure, and decrease their work effort. This would explain why poor agents supply more labor than wealthier agents do, which attenuates the effect of inequality in the capital endowments.

reform steady state. The direct solution of the non-linear system avoids the use of a log linear approximation of the equations, as is often done in solving DSGE models with the approach of Blanchard and Khan (1980) and Sims (2001).[15] This study compares the transition path of the economy between steady states, going beyond the tracing of the fluctuations around an initial steady state through impulse response functions.

The model used here also modifies Tourinho and Brum (2020) in other directions, besides inclusion of household heterogeneity described above. First, the calibration was revised to improve the empirical estimates of several key parameters, and to estimate the parameters introduced by the disaggregation of household types. Second, it considers an open economy, by including foreign sector variables and an equation for the balance of payments, albeit in a very simplified manner.[16] Surprisingly, the Papageorgiou model considers a closed economy, in spite of the fact that the foreign sector is very significant in Greece. More generally, the cursory examination of the recent cases of debt consolidation in Europe shows the importance of this extension. For Brazil, this is important in spite of the fact that trade flows are relatively small, because foreign savings are large relative to total investment and play an important role in refinancing the public debt.[17]

The Brazilian literature includes several studies that use calibrated DGE models to analyze the long-run dynamic macroeconomic effects of fiscal policy. Araujo and Ferreira (1999) investigate both welfare and output effects triggered by reforms in the tax system. When the government increases the tax rate on consumption and on investment, while cutting the tax rate on labor and capital income, it induces a sharp rise in working hours and a short-run reduction in private consumption and, hence, a welfare loss. Nevertheless, the long-run effects of such policy are positive in terms of output, employment and capital stock. Santana et al. (2012) show that a reduction of the tax burden accompanied by a cut in public consumption to balance the budget has a negligible effect on output, and claim that the best policy to provide a long-run stimulus is to increase public investment using the fiscal slack obtained by reducing public consumption. Both of these works assume the absence of government debt, while the following ones incorporate it. Pereira and Ferreira (2010) employ a dynamic recursive model to assess the effects on the Brazilian economy of a tax reform, assuming a balanced budget.

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[15] The log linearization of the equation system also introduces approximation errors that may be significant, especially when performing dynamic simulations that involve transitions between steady states.

[16] Since the focus here is domestic debt, the model here emphasizes the capital account.

[17] For the positive effect of openness in foreign trade on growth see, for example, Frankel and Romer (1999). For a more skeptical assessment of that relation see, for example, Rodriguez and Rodrik (2001).

They find that a cut in tax rate on capital income yields positive long-run effects on the growth rate, private consumption, labor supply and wages. The effects are milder when the government also implements an exemption from the payroll tax or reduces the cumulativeness of the tax system. Bezerra et al. (2014) analyze the long run effects of a change in the fiscal mix, in which public enterprises increase the infrastructure investments, concluding that this increases output and leads to welfare gains. Tourinho et al. (2013) consider a simpler disaggregation for taxes and spending but allow for the existence of public debt and test its sustainability. They employ a dynamic stochastic general equilibrium model (DSGE) calibrated for the Brazilian economy suggest that a reduction in public spending implies in a crowding-in effect and a gradual reduction of the interest rates. There are several other significant differences between these models and ours concerning the formulation of the utility function of households, the supply of labor, and the nature of the aggregate production function, some of which are discussed in the following sections.

The rest of this chapter is as follows. Section 1.2 presents the specification of the model, and section 1.3 shows the equations for the steady state and dynamic equilibriums. Section 1.4 summarizes the calibration of parameters of the model for the Brazilian economy in 2016. Section 1.5 discusses the effects of fiscal mix changes and of debt consolidation strategies aiming at reducing the public debt and stabilizing it at this lower long run level. The last section contains final considerations and conclusions.

1.2 Model Specification

As indicated in the Introduction, the model developed here is an extension of Papageorgiou (2012) to consider two types of households and an open economy, so it inherits several of its characteristics. Its formulation is presented below following the base model as closely as possible, to facilitate comparisons.

1.2.1 Households

The number of households is denoted N_t which is assumed to increase at a rate γ_n, so $N_{t+1} = \gamma_n N_t$. The two types of households, Ricardian and non-Ricardian, are denoted $\hbar = R$ and NR, respectively. Households are identical within the groups corresponding to each of these two types. Their numbers are N_t^R and N_t^{NR}, $N_t = N_t^R + N_t^{NR}$, and the proportion of non-Ricardian households is $\lambda = N_t^{NR}/N_t$, and that of Ricardian households is $(1-\lambda) = N_t^R/N_t$. The aggregate per-capita level of any household variable, represented by X_t in the following equation, is a weighted average of its value for each of the two household types, following Forni et al. (2009):

$$X_t = \lambda X_t^{NR} + (1-\lambda) X_t^R \tag{1.1}$$

Both households have an infinite horizon, and choose the path of consumption to maximize the present value of utility discounted at a rate ρ^{*t}, so that the corresponding discount factor is $\beta^{*t} = 1/(1+\rho^*)^t$.

$$U_\hbar = \sum_{t=0}^{\infty} \beta^{*t} u(C_t^\hbar + \vartheta \bar{G}_t^c, L_t^\hbar) \ , \qquad \text{for } \hbar = R \text{ and } NR \tag{1.2}$$

where $C_t^\hbar$ and $L_t^\hbar$ are, respectively, private consumption and leisure of each household of type $\hbar$, $\bar{G}_t^c$ is the average consumption of public goods per household, i.e. $\bar{G}_t^c = G_t^c/N_t$. Total consumption of each household is a linear aggregate of private goods and average public goods consumption, and the substitution factor between them is $\vartheta \in [-1,1]$. Note,3 however, that $\bar{G}_t^c$ and ϑ are not distinguished by household type. There is a tradeoff between total consumption and leisure with unit elasticity of substitution, i.e. utility is a Cobb-Douglas (henceforth C-D) aggregate of private consumption and leisure, with parameter $\gamma \in (0,1)$. Hence, their share in total household expenditure is constant, and labor supply is endogenous. Further, the instantaneous utility u is taken to be a CRRA function with parameter $\sigma \geq 1$: [18]

$$u(C_t^\hbar + \vartheta \bar{G}_t^c, L_t^\hbar) = \frac{\left[(C_t^\hbar + \vartheta \bar{G}_t^c)^\gamma (L_t^\hbar)^{1-\gamma} \right]^{1-\sigma}}{1-\sigma}, \qquad \text{for } \hbar = R \text{ and } NR \tag{1.3}$$

In the static stochastic context, σ is the relative risk aversion coefficient, and in the dynamic deterministic context $1/\sigma$ is the intertemporal elasticity of substitution. This means

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[18] See Rubinstein (1976) for a strong case in favor of this specification for models of financial decisions.

that larger values of σ imply that households are less willing to substitute future for present consumption.[19] For simplicity, it does not vary across household types in the model described in this chapter, but this restriction is relaxed in the later chapters.

Both types of households choose consumption to maximize the present value of the flow of utilities, as indicated in equations (1.1) and (1.2), starting from a known initial steady state. The optimal plan must satisfy the static and dynamic equations that characterize the economy, as well as the transversality condition that avoids non-stationary behavior as time increases indefinitely. However, the budget constraints of the two types of households are different, and their decision rules reflect this fact. The Ricardian households can lend, borrow, and invest, while the non-Ricardian households have their consumption constrained by current income (Campbell and Mankiw (1989) and Forni et al. (2008)).[20]

The budget constraint of the Ricardian households is:

$$\begin{aligned}&(1+\tau_t^c)C_t^R + I_t^R + D_t^R \\ &= (1-\tau_t^{LR})w_t^R Z_t H_t^R + \left(1-\tau_t^k\right)\left(r_t^k K_t^R + \pi_t^R\right) + r_t^b B_t^R + \omega^R \bar{G}_t^{tr} + \tau_t^k \delta^p K_t^R \qquad (1.4)\end{aligned}$$

where the left side shows the allocation of income to: (i) consumption (C_t^R) plus its *ad valorem* tax with rate τ_t^c, (ii) saving for investment in physical capital (I_t^R), and (iii) saving for the purchase of government bonds (D_t^R). The right side shows the sources of income: (i) labor income, which is equal to the product of the wage (w_t^R) and the number of hours worked (H_t^R) and the exogenous productivity of labor (Z_t),[21] net of the *ad valorem* tax on Ricardian labor income with rate τ_t^{LR}; (ii) capital income, which is equal to the sum of the return on physical capital (K_t^R) at a rate r_t^k, plus the dividends distributed by the firms (π_t^R), net of the tax on capital income with an *ad valorem* tax rate τ_t^k; (iii) the interest on government bonds (B_t^R), at a rate r_t^b; (iv) the share ω^R of average government transfers per household $(\bar{G}_t^{tr} = G_t^{tr}/N_t)$; and (v) the tax credit, at a rate τ_t^k, of the depreciation of physical capital at a rate δ^p.

The following state transition equations must also be satisfied:

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[19] See Thimme (2017) for a recent survey on empirical estimates of the elasticity of intertemporal substitution in consumption and its relation to the relative risk aversion coefficient.

[20] This setup is reminiscent of the Uzawa (1961, 1963) two-sector models of exogenous growth, where workers rely only on labor income for consumption, and capitalists save all their income, specialized to the case where there is no difference in the production function of the consumption and capital goods sectors. Since the difference in the marginal productivity of capital in the two industries plays an important role for the stability of that model (Solow, 1961), there could be some concern regarding instability in the model specified here, but not problems were observed in that regard.

[21] Technological progress grows geometrically, so $Z_{t+1} = \gamma_z Z_t$, where $\gamma_z > 1$ and $Z_0 > 0$ are given.

$$K_{t+1}^{R} = (1-\delta^{p})K_{t}^{R} + I_{t}^{R} \tag{1.5}$$

$$B_{t+1}^{R} = B_{t}^{R} + D_{t}^{R} \tag{1.6}$$

The non-Ricardian households do not own shares of firms or physical capital, and therefore do not receive dividends or capital income, and do not borrow or lend, so their budget constraint is:

$$(1+\tau_{t}^{c})C_{t}^{NR} = (1-\tau_{t}^{LNR})w_{t}^{NR}Z_{t}H_{t}^{NR} + \omega^{NR}G_{t}^{tr} \tag{1.7}$$

where the left-hand side indicates that the only use of income is for consumption (C_{t}^{NR}) net of its *ad valorem* tax, with a rate τ_{t}^{c}. The right-hand side indicates that the sources of income are: (i) the product of the wage (w_{t}^{NR}), the number of hours worked (H_{t}^{NR}) and the exogenous productivity of labor (Z_{t}), net of the *ad valorem* labor income tax, with rate τ_{t}^{LNR}; and (ii) the share ω^{NR} of average government transfers to households (G_{t}^{tr}). There are no state transition equations.

The endowment of hours of each household type is equal to one, and is allocated to leisure or work, so the resource constraints are:

$$L_{t}^{R} + H_{t}^{R} = 1, \text{ and } L_{t}^{NR} + H_{t}^{NR} = 1 \tag{1.8}$$

The solution of the planning problem of each of the two household types takes the fiscal policy parameters as chosen by the Government, and are therefore exogenous, the prices w_{t}^{R}, $w_{t}^{NR}, r_{t}^{k}, r_{t}^{b}, \pi_{t}^{R}$ as given and, starting from the initial values of the variables, yields trajectories $\{C_{t}^{R}, L_{t}^{R}, H_{t}^{R}, I_{t}^{R}, D_{t}^{R}, K_{t+1}^{R}, B_{t+1}^{R}\}_{t=0}^{\infty}$ and $\{C_{t}^{NR}, L_{t}^{NR}, H_{t}^{NR}\}_{t=0}^{\infty}$.

1.2.2 Firms

There are N_{t} identical firms producing a homogenous good that serves indistinctly for consumption or investment of households and government.[22] This good is the *numeraire,* and its price is set to one. The output of each firm is Y_{t}^{f}, and the technology is a C-D production function that combines the firm's private capital $\left(K_{t}^{f}\right)$, labor in efficiency units $\left(H_{t}^{f}\right)$, and the average public capital *per firm* at the beginning of period t $(\bar{K}_{t}^{g})$, with elasticities respectively equal to α_{1}, α_{2} and α_{3}:

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[22] For simplicity, the number of firms is set equal do the total number of households.

$$Y_t^f = \left(K_t^f\right)^{\alpha_1}\left(Z_t H_t^f\right)^{\alpha_2}\left(\bar{K}_t^g\right)^{\alpha_3} \tag{1.9}$$

Firms behave competitively taking $\bar{K}_t^g$ as exogenously determined. Profit maximization with prices of capital and labor, equal to r_t^k and w_t, respectively, implies that the shares of each factor are constant, and equal to the corresponding elasticity:

$$r_t^k = a_1 Y_t^f / K_t^f \tag{1.10}$$

$$w_t = a_2 Y_t^f / Z_t H_t^f \tag{1.11}$$

For simplicity, it is also assumed that there are constant returns to scale, so $\alpha_1 + \alpha_2 + \alpha_3 = 1$. Therefore, profits are null ($\pi_t^f = 0$) and, therefore, dividends distributed to the Ricardian households are also null ($\pi_t^R = 0$).

Equilibrium of the factor markets require that the aggregate demand derived from equations (1.10) and (1.11) be consistent with supply.

Ricardian households own the total capital of firms so, using equation (1.1):

$$K_t^f = (N_t^R / N_t) K_t^R = (1 - \lambda) K_t^R \tag{1.12}$$

Labor services provided by the two types of households are different, and are combined in a C-D aggregation function with parameter ϕ to produce the composite labor input $\left(H_t^f\right)$:

$$H_t^f = (H_t^{NR})^{\phi} (H_t^R)^{(1-\phi)} \tag{1.13}$$

Using equation (1.1) and noting that $N_t \equiv {N_t}^{\phi} {N_t}^{1-\phi}$, aggregate labor demand is:

$$N_t H_t^f = \left(\frac{N_t^{NR} H_t^{NR}}{\lambda}\right)^{\phi} \left(\frac{N_t^R H_t^R}{(1-\lambda)}\right)^{(1-\phi)} \tag{1.14}$$

The representative firm chooses the composition of the labor input that maximizes profit by taking w_t^R and w_t^{NR} as given, so that the value of the composite wage w_t is given by Equation (1.11) and the total wage bill is $w_t H_t^f N_t = w_t^{NR} H_t^{NR} N_t^{NR} + w_t^R H_t^R\, N_t^R$, which reduces to:

$$w_t H_t^f = \lambda w_t^{NR} H_t^{NR} + (1 - \lambda) w_t^R H_t^R \tag{1.15}$$

Since the labor aggregation technology displays constant returns to scale and has unitary elasticity of substitution, the share of total labor income that accrues to each of the two household types is equal to $(1 - \phi)$ and ϕ, for $\hbar = R$ and NR respectively, which are the ratios of the terms in the right-hand side to the one in the left-hand side of equation (1.15):

$$\left(w_t^{NR} H_t^{NR} / w_t H_t^f\right) = \phi / \lambda \tag{1.16}$$

$$\left[w_t^R H_t^{NR} / w_t H_t^f\right] = (1 - \phi)\, / (1 - \lambda) \tag{1.17}$$

In the formulation above the production plan to produce Y_t^f is determined in two stages: first, the firm decides on the desired quantities of capital $\left(K_t^f\right)$ and composite labor $\left(H_t^f\right)$ based on the aggregate wage, and then decides on how to combine the two labor types to obtain the latter, based on their relative wage.

1.2.3 Government

There are seven fiscal policy instruments: (*i*) four taxes: on consumption, on income from capital and on income of the two types of labor (Ricardian and of non-Ricardian), with rates respectively equal to τ_t^c, τ_t^k, τ_t^{LR} and τ_t^{LNR}, and (*ii*) three aggregate public expenditures *per household*:[23] public consumption (G_t^c), lump-sum transfers to households (G_t^{tr}), and public investment $\left(G_t^i\right)$. The government's budget constraint is:

$$
\begin{aligned}
& N_{t+1}^R B_{t+1}^R + \tau_t^c N_t^R C_t^R + \tau_t^c N_t^{NR} C_t^{NR} + \tau_t^{LR} w_t^R Z_t N_t^R H_t^R + \tau_t^{LNR} w_t^{NR} Z_t N_t^{NR} H_t^{NR} \\
& + \tau_t^k \left[\left(r_t^k - \delta^p \right) N_t^R K_t{}^R + N_t \pi_t^f \right] + F_t \\
& = N_t \bar{G}_t^c + N_t \bar{G}_t^{tr} + N_t \bar{G}_t^i + \left(1 + r_t^b\right) N_t^R B_t^R + r_t^F N_t B_t^F \qquad (1.18)
\end{aligned}
$$

where the left-hand side indicates the sources of revenue, and the right-hand side indicates its uses. The total after-tax consumption and labor income are equal, respectively, to the sum of the consumption and labor income of the two household types. The average value of each of these aggregates follows equation (1.1), but the after-tax capital income accrues only to Ricardian households, as indicated earlier. There is no inflation, nor the corresponding tax. The government deficit is financed by issuing public debt, which may be domestic (B_t^R) or foreign (B_t^F), with interest rates are r_t^b and r_t^F, respectively. Domestic government debt is retired and issued again each period, and its interest rate is endogenous. Foreign government debt is exogenous, and only its interest cost enters the government budget. Aggregate inflow of foreign savings in the form of new indebtedness or direct investment per household is F_t, and is exogenous. It finances the current account deficit, since foreign reserves are constant, by

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[23] Please note the notation here is different from Papageorgiou (2012).

assumption.[24] This very simplified formulation of the openness of the economy is sufficient to capture the crucial fact that the inflow of foreign savings has represented historically an important source of funds for financing the Brazilian budget deficit, and turns out to be very useful to calibrate the model consistently with the recently observed public expenditures ratios.

The law of motion of public capital per household is:

$$K_{t+1}^{g} = (1-\delta^{g})K_{t}^{g} + G_{t}^{i} \tag{1.19}$$

1.3 Equilibrium

Equality of supply and demand, taking into account that the number of firms and households it equal to N_t, implies:

$$Y_{t}^{f} = C_t + I_t + \bar{G}_{t}^{c} + \bar{G}_{t}^{i} - F_t \tag{1.20}$$

The transversality condition requires that the present value of the terminal public debt converge as the horizon of the model extends forever. This eliminates solutions where the trajectory of public debt is explosive.

$$\lim_{T\to\infty}\left(\prod_{j=1}^{T}(1+r_{j}^{b})^{-1}\right)B_{T+1}^{R} = 0 \tag{1.21}$$

The model equilibrium of the model in stationary variables is obtained by rewriting the equation system while expressing the endogenous variables in effective labor units. These are denoted by the lowercase letters corresponding to the upper case variables defined earlier, and formally defined as follows: $x_{t}^{h} = X_{t}^{h}/N_t Z_t$, $x_{t}^{f} = X_{t}^{f}/{N_t}^{f} Z_t$ and $x_t = X_t/N_t Z_t$, where X_{t}^{h} denotes a generic per household variable, X_{t}^{f} is a generic per firm variable, and X_t is a generic average level of any household variable, calculated according to equation (1.1).

This yields a system of twelve dynamic equations for trajectories of the variables $(y_t, c_t, c_{t}^{R}, c_{t}^{NR}, i_t, h_t, h_{t}^{R}, h_{t}^{NR}, k_{t+1}, k_{t+1}^{g}, r_{t}^{b}, b_{t+1})$, where $y_t, i_t, h_t,$ and k_t are per firm

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[24] This is a simplifying assumptionand considers that this flow may depend on numerous exogenous factors related to the conditions of international financial markets. A more complete treatment can be found in Maldonado, Tourinho and Valli (2007) that formulates, calibrates, and simulates a CGE where foreign savings flow is endogenous, and responds to an empirically estimated schedule that relates it to the rate of change of foreign reserves. Roughly speaking, it captures the idea that foreign investors see foreign reserves as collateral for their investment in the country.

variables (with the superscript f omitted), which are reconciled with the corresponding Ricardian household variables by the equations formerly discussed.

$$\frac{(c_t^R + \vartheta g_t^c)}{y} = \frac{(1-\phi)}{(1-\lambda)} \alpha_2 \frac{(1-\tau_t^{LR})}{(1+\tau_t^c)} \frac{\gamma}{(1-\gamma)} \; \frac{(1-h_t^R)}{h_t^R} \tag{1.22}$$

$$\frac{(c_t^{NR} + \vartheta g_t^c)}{y} = \frac{\phi}{\lambda} \alpha_2 \frac{(1-\tau_t^{LNR})}{(1+\tau_t^c)} \frac{\gamma}{(1-\gamma)} \; \frac{(1-h_t^{NR})}{h_t^{NR}} \tag{1.23}$$

$$\frac{\gamma_z[(c_{t+1}^R + \vartheta g_{t+1}^c)^{\gamma}(1-h_t^R)^{1-\gamma}]^{1-\sigma}}{(1+\tau_t^c)(c_t^R + \vartheta g_t^c)}$$

$$= \beta \left[\frac{[(c_{t+1}^R + \vartheta g_{t+1}^c)^{\gamma}(1-h_{t+1}^R)^{1-\gamma}]^{1-\sigma}}{(1+\tau_{t+1}^c)(c_{t+1}^R + \vartheta g_{t+1}^c)} \left(\left(1-\tau_{t+1}^k\right) \left(\alpha_1 \frac{y_{t+1}}{k_{t+1}} - \delta^p \right) + 1 \right) \right] \tag{1.24}$$

$$r_{t+1}^b = \left(1-\tau_{t+1}^k\right) \left(\alpha_1 \frac{y_{t+1}}{k_{t+1}} - \delta^p \right) \tag{1.25}$$

$$\gamma_n \gamma_z k_{t+1} = (1-\delta^p) k_t + i_t \tag{1.26}$$

$$\gamma_n \gamma_z k_{t+1}^g = (1-\delta^g) k_t^g + g_t^i \tag{1.27}$$

$$y_t = (k_t)^{\alpha_1} (h_t)^{\alpha_2} \left(k_t^g\right)^{\alpha_3} \tag{1.28}$$

$$h_t = (h_t^{NR})^{\phi} (h_t^R)^{(1-\phi)} \tag{1.29}$$

$$y_t = c_t + i_t + \; g_t^c + g_t^i - f_t \tag{1.30}$$

$$c_t = \lambda c_t^{NR} + (1-\lambda) c_t^R \tag{1.31}$$

$$\gamma_n \gamma_z b_{t+1} + \tau_t^c c_t + [\tau_t^{LNR} \, \phi \, \alpha_2 + \tau_t^{LR} \, (1-\phi)\alpha_2 + \tau_t^k (\alpha_1 + \alpha_3)] y_t - \; \tau_t^k \delta^p k_t$$

$$= g_t^c + g_t^i + g_t^{tr} + \left(1 + r_t^b\right) b_t + r_t^f b_t^f - f_t \tag{1.32}$$

$$(1-\tau_t^{LR}) \frac{(1-\phi)}{(1-\lambda)} \alpha_2 y_t + \left(1-\tau_t^k\right)(\alpha_1) y_t + r_t^b b_t + g_t^{tr} + \tau_t^k \delta^p k_t^R$$

$$= (1+\tau_t^c) c_t^R + i_t^R + d_t^R \tag{1.33}$$

The system of equations (1.22) to (1.33) is determined, to the extent that it has identical number of equations and endogenous variables for each period *t*, as long as their initial values and the exogenous fiscal policy instruments are given. The latter are rates of the *ad valorem* taxes on consumption, on labor and on capital income $\left(\tau_t^c, \tau_t^{LNR}, \tau_t^{LR}, \tau_t^k\right)$ and average household Government consumption, investment, and transfers (g_t^c, g_t^i, g_t^{tr}).

The budget constraints of the government and the Ricardian households enter the system (equations (1.32) and (1.33), respectively), but the budget constraint of the non-Ricardian households (derived from equation (1.7)) is omitted. This follows from a corollary of Walras' Law, which states that in the equilibrium of an exchange economy with N consumers, if N - 1 of them satisfy the budget constraint, the budget for *N*th consumer is also satisfied. [25]

The numerical solution of the system yields dynamic equilibrium perfect forecast trajectories of the variables. To calculate it a software tool that allows its convenient algebraic specification, enables the use of a very efficient and precise routine for the solution of the resulting non-linear system of equations, and facilitates the simulation of different fiscal policies is used.[26]

To obtain the long-run steady state (SS) solution from the dynamic system, the required condition is that the endogenous variables (x) be stationary, i.e. $x_{t-1} = x_t$ for all *t*. This yields the following system of equations equation, used to calibrate the model.

$$\frac{k}{y} = \frac{\beta\alpha_1(1-\tau^k)}{\gamma_z + \beta[(1-\tau^k)\delta^p - 1]} \tag{1.34}$$

$$\frac{i}{y} = [\gamma_z\gamma_n - (1-\delta^p)]\frac{k}{y} \tag{1.35}$$

$$r^b = (1-\tau^k)\left(\alpha_1\frac{y}{k} - \delta^p\right) \tag{1.36}$$

$$\frac{c}{y} = 1 - \frac{i}{y} - \frac{g^c}{y} - \frac{g^i}{y} - \frac{f}{y} \tag{1.37}$$

$$\frac{c}{y} = \lambda\frac{c^{NR}}{y} + (1-\lambda)\frac{c^R}{y} \tag{1.38}$$

$$h^R = \frac{\left[\frac{(1-\phi)}{(1-\lambda)}\alpha_2\left(\frac{\gamma}{(1-\gamma)}\right)\left(\frac{1-\tau_t^{LR}}{1+\tau^c}\right)\right]}{\frac{c^R + \vartheta g^c}{y} + \left[\frac{(1-\phi)}{(1-\lambda)}\alpha_2\left(\frac{\gamma}{(1-\gamma)}\right)\left(\frac{1-\tau_t^{LR}}{1+\tau^c}\right)\right]} \tag{1.39}$$

$$h^{NR} = \frac{\left[\frac{\phi}{\lambda}\alpha_2\left(\frac{\gamma}{(1-\gamma)}\right)\left(\frac{1-\tau_t^{LNR}}{1+\tau^c}\right)\right]}{\frac{c^{NR} + \vartheta g^c}{y} + \left[\frac{\phi}{\lambda}\alpha_2\left(\frac{\gamma}{(1-\gamma)}\right)\left(\frac{1-\tau_t^{LNR}}{1+\tau^c}\right)\right]} \tag{1.40}$$

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[25] The model here extrapolates this result to an open economy with production and Government.

[26] This model uses the *General Algebraic Modeling System* (GAMS) to specify the model and perform the simulations, employing the routine PATH for the numerical solution of non-linear equation systems.

$$\frac{k^g}{y} = \left(\frac{g^i}{y}\right)/\gamma_z\gamma_n - (1-\delta^g) \tag{1.41}$$

$$1 = \left(\frac{k}{y}\right)^{\alpha_1}\left(\frac{h}{y}\right)^{\alpha_2}\left(\frac{k^g}{y}\right)^{\alpha_3} \tag{1.42}$$

$$h = (h^{NR})^{\phi}(h^R)^{(1-\phi)} \tag{1.43}$$

$$\frac{b}{y}[\gamma_z\gamma_n - (1-r^b)] + \frac{c}{y}\tau^c + \tau^{LNR}\phi\alpha_2 + \tau^{LR}(1-\phi)\alpha_2 + \tau^k(\alpha_1+\alpha_3) + \frac{f}{y}$$

$$= \frac{g^c}{y} + \frac{g^{tr}}{y} + \frac{g^i}{y} + \frac{b^f}{y}\, r^f \tag{1.44}$$

$$(1+\tau^c)\frac{c^R}{y} + \frac{i}{y}$$

$$= (1-\tau_t^{LR})\frac{(1-\phi)}{(1-\lambda)}(\alpha_2) + (1-\tau^k)(\alpha_1) + r^b\frac{b}{y} + \omega^R\frac{g^{tr}}{y} + \tau_t^k\delta^p\frac{k}{y} \tag{1.45}$$

To assess the impact on the households' welfare, Lucas' (1990) metric is used. It is the consumption subsidy necessary to keep the households indifferent between the situation before and after the fiscal policy change. Denoting V_0^h the discounted flow of utility in the initial steady state, and V^{*h} its value after the fiscal policy change, the permanent proportional consumption subsidy is ξ^h:

$$\xi^h = (V^{*h}/V_0^h)^{\frac{1}{\gamma(1-\sigma)}} - 1 \qquad \hbar = R \text{ and } NR \tag{1.46}$$

This variable is positive ($\xi^h > 0$) when there is a welfare increase and is negative ($\xi^h < 0$) when there is a welfare reduction. In the heterogeneous household case, it is also possible to calculate an aggregate social welfare index in the spirit of Negishi (1960) as the weighted average index of the welfare index for the two household types, using their shares as weights (see equation (1.1)):

$$\xi = \lambda\xi^{NR} + (1-\lambda)\xi^R \tag{1.47}$$

This index indicates how the average consumer would value the different policies, in an economy where all households have equal weight. The policy that attains the largest ξ would presumably be the one chosen in an election where each household has one vote.

1.4 Calibration of the Model for the Brazilian Economy

As usual in applied general equilibrium studies, the calibration of the model reflects the state of the economy at the base date, the end of 2016, assuming that it was in a steady state (SS) on that occasion and, therefore, satisfies equations (1.34) to (1.45). The main data sources are the National Accounts calculated (IBGE (2018)), the Social Accounting Matrix in Tourinho et al. (2006), and the reports (IFI (2018)) on the fiscal situation. Table 1.1 summarizes the parameters of the calibrated model.

The parameter σ that indicates the elasticity of intertemporal substitution $(1/\sigma)$ is of fundamental importance for the determination of the intertemporal choices that define the trajectory of the public debt. Lucas (1990) uses $\sigma = 2$ for the US economy, as do Baier and Glomm (2001). For developing countries, Liu and Sercu (2009) estimate $1/\sigma = 0.5$. Lluch, Powel and Williams (1977) estimate an extended linear expenditure (ELES) for several countries and estimate a value for the Frisch parameter that implies $1/\sigma = 0.3$ for developing countries like Brazil. Papageorgiou (2012) adopted $\sigma = 2$ for Greece, citing its widespread use. Mereb and Zilberman (2013) choose $\sigma = 3$ for Brazil claiming that an intermediate value between the parameters in the literature for developed and developing nations would be justified. Here that parameter is calibrated as $\sigma = 2$, i.e. $1/\sigma = 0.5$.

The parameter ϑ, which indicates the rate of substitution between public and private consumption, was set to 0.1. This is approximately equal to the share of public spending on aggregate income in Brazil, [27] and is the value used by Baxter and King (1993), Baier and Glomm (2001), Leeper et al. (2010) for the USA, and Papageorgiou (2012) for Greece. The value $\vartheta = 0.5$ used in some studies in the Brazilian literature, like Ferreira and Nascimento (2005), Santana et al. (2012) and Bezerra et al. (2014) appears to be inconsistent with the revealed preference of households.

To reduce measurement errors and represent more properly an approximate steady state, the average value of the macroeconomic aggregates over the period 2010 to 2016 was calculated from the National Accounts for Brazil (IBGE (2018)). This is consistent with the data because the expenditure shares were rather stable during that period, except for 2016, when the share

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[27] Excluding transfers from the public expenditures, one can measure the household consumption of public goods as the sum of “Compensation of Employees” (4.0% of GDP) and “Other Current Expenditure” (5.3% of GDP) in the National Accounts.

consumption increased 2 p.p. (percentage points) to the detriment of that of public investment. To take this into consideration its share was set to the value observed in 2015: $c/y = 0.62$, and the investment share was set to its average between 2010 and 2014: $i/y = 0.16$. For the share of consumption of public goods, the value observed in 2015 was used: $g^c/y = 0.20$.

The value in the World Bank's WDI database for 2015 was used for the population growth rate ($\gamma_n = 1.0086$). Following Papageorgiou (2012), the growth rate of per capita GDP in the USA (2% per year) was used for the growth rate of labor augmenting technical progress γ_z.[28] The initial level of the technical progress parameter (Z_0) was set to one. The parameter of the Cobb-Douglas consumption aggregator function ($\gamma = 0.434$) was set to be consistent with the share of hours devoted to work in the total time endowment ($h = 0.24$) in the PNAD 2009 survey (IBGE (2018)).

Due to the constant returns of scale assumption (equations 1.10 and 1.11), the production function parameters were set to the recent factor expenditure shares. The average share of the public investment observed between 1995 and 2017 was $\alpha_3 = (gi/y) = 0.0322$, according to IFI (2018). [29] The application of the methodology in Gollin (2002) [30] to 2015 data yielded a value for the output elasticity of labor, $\alpha_2 = 0.6223$, that is consistent with the ones found in Ferreira and Nascimento (2006), Santana et al. (2012) and Mereb and Zilberman (2013). The output elasticity of private capital was obtained as a residual, $\alpha_1 = 1 - \alpha_2 - \alpha_3 = 0.3455$. The depreciation rate of total physical capital was set to 3.5% per year, which is the value estimated by Gomes et al. (2003) by applying the permanent inventory methodology on the investment series of the National Accounts. The same value was used for public and private capital, $\delta^p = \delta^g = 0.035$. [31] The capital to output ratio ($k/y = 2.535$) was obtained from equation (1.35), and equation (1.41) then yields $k^g/y = 0.503$. [32]

The tax rates used were those calculated by Santana et al. (2012) for 2010, $\tau^c = 0.1902$, $\tau^{LR} = \tau^{LNR} = 0.2171$, and $\tau^k = 0.13$ since they are more consistent with a virtual steady state for 2016 than those inferred from 2015 data that was distorted by the fiscal imbalance in that

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[28] Barbosa Filho et al. (2010) indicate that between 1992 and 2007 the total factor productivity in Brazil grew only 11.3%, with an average rate of 0.71% per year.

[29] Ferreira and Nascimento (2006), and Santana et. al. (2012) use endogenous growth models and adopt higher value for that parameter.

[30] The formula used is $(RE + RMB)/(RE + RMB + EOB)$, where RE is the labor income, RMB is the Gross Mixed Income and EOB is the Gross Operating Surplus.

[31] Santana et al. (2012) also used this value. Some authors use higher depreciation rates, but they are inconsistent with the investment series.

[32] The value found is higher than the one estimated by Bezerra et al. (2014) (0.3577) but is compatible with the value calculated from the IMF (International Monetary Fund) data (0.4494) by assigning half of the private-public partnerships to public capital, and the other half to private capital.

year.[33] Almeida et al. (2017) and Azevedo and Fasolo (2015a, 2015b) show that those rates are representative for the period 2010 to 2014. The set of parameters discussed previously allows the calibration of the discount factor using equation (1.34), which yields $\beta = 0.937$.

The public debt to GDP ratio observed in December 2015 was $b/y = 0.66$, and it was assumed to be the target long-run value for indebtedness. Use of the Fischer relation to exclude inflation from the nominal interest rate on the internal gross debt permitted the calculation of the real rate of return on public bonds gross of taxes to be 6.88% per year.[34] The net real interest rate on public debt, 5.75% per year, was obtained by deducting the average tax rate on this type of income (16.5%) from the gross rate.[35] Since the analysis here is prospective, we round up this value to $r^b = 0.06$.

The fraction of non-Ricardian households ($\lambda = 0.70$) was calibrated by using the income distribution of the Social Accounting Matrix (SAM) for Brazil in 2003 (Tourinho et al. 2006), and assuming that the non-Ricardian cohort is composed of the households in income class D plus half of the households in income class C. This fraction is very similar to the one calculated by Gomes (2013) from indirect evidence on the elasticity of private consumption with respect to income in Brazil. The parameter of the aggregation function for the types of labor supplied by each type of household ($\phi = 0.34$) was calculated from equation (1.16) using the labor income shares obtained from the SAM for 2003 and the calibrated value of λ. Hence, the elasticity of aggregate labor with respect to the labor provided by Ricardian households is $(1 - \phi) = 0.66$, implying that the productivity of the labor services they provide is, roughly speaking, twice that of non-Ricardian households. Finally, it is assumed that government lump-sum income transfers benefit the households evenly, so $\omega^{nr} = 1$ and $\omega^r = 1$.

To calibrate the parameters and steady state values of the variables that represent the foreign sector we consider that the flows of goods and services in foreign trade are exogenous. The *external* debt per unit of labor (b^f) was assumed to remain constant over time, and its value was set so that $b^f/y = 26.3\%$ which is the ratio of the net external liabilities to GDP in 2015.[36] The interest rate on this debt $r^f = 5\%$ was calculated as the sum of the average expected Fed funds rate in the US and the average EMBI+ Brazil rate. Finally, the average

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[33] These values are also consistent with those calculated by Bezerra et. al. (2014), also for 2010, since the differences are, broadly speaking, due to the differences in the specification of their models.

[34] The IPCA variation in 2015 was 10,67%. Source: IBGE (2018) – Synoptic Table 1 National Accounts and the gross rate of return of domestic public debt was equal to the SELIC rate, calculated by the Central Bank of Brazil to have been 13,3% per year on average for 2015.

[35] This calculation takes into account the distribution of maturity of the total federal public debt in December 2016 (see STN (2016)) and the maturity-dependent tax brackets (ANDIMA, 2018).

[36] See Ribeiro (2016).

current account deficit between 2010 and 2015 is used to calibrate the flow of foreign savings: f/y = 0.033.

Table 1.1 – Calibrated parameters for Brazil in 2016

Parameter or variable	Description	Value
β	Time discount factor	0.937
σ	Relative risk aversion coefficient (CRRA utility)	2
ϑ	Substitutability between private and public consumption	0.1
γ	Weight of total consumption in utility function	0.434
γ_n	Population growth rate	1.0086
γ_z	Growth rate of labor augmenting technology	1.02
Z_0	Initial level of total factor productivity	1
i/y	Private investment to output ratio	0.16
c/y	Private consumption to output ratio	0.62
k/y	Private capital to output ratio	2.535
k^g/y	Public capital to output ratio	0.503
α_1	Elasticity of output with respect to private capital	0.3455
α_2	Elasticity of output with respect to labor	0.6223
α_3	Elasticity of output with respect to public capital	0.0322
δ^p	Depreciation rate of private capital	0.0345
δ^g	Depreciation rate of public capital	0.0345
g^c/y	Government consumption to output ratio	0.20
g^i/y	Government investment to output ratio	0.0322
g^{tr}/y	Government transfers to output ratio	0.041
λ	Proportion of non-Ricardian households	λ = 0.70
ϕ	Cobb-Douglas parameter of labor aggregation function	ϕ = 0.34
ω^h	Share of households in government transfers	ω^R = 1 ω^{NR} = 1
τ^c	Tax rate on consumption	0.1902
τ^L	Tax rate on labor income	$\tau^{LR} = \tau^{LNR} = 0.2171$
τ^k	Tax rate on capital income	0.13
b/y	Public debt to output ratio	0.66
b^f/y	Foreign public debt to output ratio	0.263
r^b	Real return to government bonds	0.06
r^f	Real return to government bonds issued in the foreign market	0.05
f/y	Foreign savings to output ratio	0.033

Following usual practice, it is assumed that the economy is in a (virtual) steady state at the initial date,[37] and the share of transfers in GDP (g^{tr}/y) is used as the as the adjustment variable, to take up the slack between the data and the equation system for the SS equilibrium. Considering a steady state level of public domestic debt of 66% of GDP, this implies a value of $g^{tr}/y = 4.1\%$, which is about half of its observed value in 2016 (9.4%).[38] This steady state path is the *virtual* benchmark equilibrium with which the fiscal policy simulations in the next section are compared.

1.5 Fiscal Policy Simulations

Following Papageorgiou (2012), this section performs two types of policy simulations: fiscal mix changes, and debt consolidation exercises.[39] The first type follows the approach proposed by Cooley and Hansen (1992) and involves changing one of the fiscal parameters and compensating its effects on the budget by changing another parameter, while keeping all the other parameters fixed at their initial level. The strategy is to maintain the modified values of the two parameters throughout the whole-time horizon and evaluate the desirability of the policy by assessing its effect on the macroeconomic aggregates and the welfare index. The second type uses a single instrument for each simulation, which takes different values in each phase of the policy. In the first phase, called *adjustment*, the instrument is set to the value required to reduce the public debt by 10 p.p. at the end of that phase.[40] In the second phase, denominated *stabilization*, the instrument is set to another value which, maintained until the end of the time horizon, will yield a terminal debt which is equal to that reduced level.

These policy simulations occur in the deterministic context and assume that at $t = 0$ the government commits itself to the future trajectory of the fiscal instruments, and that the economic agents make their plans also at $t = 0$ assuming they are credible. By hypothesis, there is no uncertainty, or problems of intertemporal consistency. The results are compared with those

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[37] This avoids biasing the simulated trajectories with effects of the transition to an initial SS equilibrium.

[38] That value was obtained by solving the system of equations (1.33) to (1.44) with the values of Table 1.1 for the other parameters. If the observed value of the public debt to GDP ratio was used in calibrating the model, that ratio of would end up following a non-stationary explosive trajectory.

[39] Performing the same type of exercises facilitates the comparison of the results. Tourinho and Brum (2020) show the result of these simulations for Brazil.

[40] Note that the reduction is in the level of public debt, not in the public debt to GDP ratio.

of the representative household model reported in Tourinho and Brum (2020), to indicate to what extent the heterogeneity of households affects the policy recommendations. It is possible that a given tax mix change or debt consolidation strategy may not Pareto optimal in the heterogeneous household context, and that therefore there will not be agreement with respect to its adoption, in spite of an improvement in the welfare of the average representative household.

1.5.1 Long-run Effects of Fiscal Mix Changes

This section describes the simulation of the effects of all possible combinations of the nine fiscal instruments and compares them. For simplicity, the tax rates on labor income of both household types are kept equal $\left(\tau_t^{LR} = \tau_t^{LNR} = \tau_t^{l}\right)$, so there are in fact only eight independent instruments and seventeen simulations. Each simulation changes only two fiscal parameters, in such a manner that their budget effects compensate each other, and obtains a new steady state (SS) with the altered parameters. For the simulations to be comparable the change in the first parameter is normalized to represent a fiscal effort equal to 1% of GDP, [41] and the value of the second parameter is obtained by solving the system of SS equations (1.34)-(1.45). The difference between this new value of the second parameter and the initial one is the compensatory variation.

Table 1.2 shows the changes in the SS values of the main endogenous variables with respect to the initial SS. The results are organized in columns, one for each experiment (numbered #1 to #17) and labeled according to the initial change of the policy, indicated in the line "Policy" and using as compensating instrument the one shown in the line "Compensation". The line "Δ Instrument" shows the magnitude of the compensatory variation, in percentage points in the case of the tax rates, or as a percentage change times 100, in the case of the other variables. For all the variables, the values shown in the table are changes relative to the initial SS, in percentages times 100.

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[41] These exercises are different from those in Papageorgiou (2012), where the initial change is equal to a 1% reduction in the rate of the chosen tax, or a 1% increase in the chosen Government expenditure. Since these changes correspond to different fiscal burdens, his experiments are not directly comparable.

The transition paths of the endogenous variables to the new SS are obtained by solving the dynamic equations (1.22) - (1.33) with the values for the fiscal parameters replaced by those of the policy being simulated, for all periods. Since all of the trajectories are smooth, and almost all of them are monotonic, the level variable in the new steady state contains the relevant information regarding the nature of the effects of the change in the fiscal mix. Figure 1.1 shows the *deviations* of the trajectory of the main variables in each case from that in the benchmark simulation. It shows the several policies grouped in columns according to the compensatory instrument, rather than the policy variable as is done in Table 1.2, and the trajectories of the endogenous variables are shown as different curves in the graphs along the column, coded as different colors according to the policy variable (see legend of Figure 1.2). This setup allows the comparison of policies from a perspective which is different from that offered by Table 1.2.

Broadly speaking, the results of Table 1.2 are similar to those for the representative household version of the model, shown in Table 2 of Tourinho and Brum (2020), because the model here is a generalization of the one there to allow household heterogeneity. The comparison of the results of these two tables shows that the magnitudes of the compensatory variation of the instruments in these two versions of the model are similar, except for g^{tr}. The main reason for this exception is the difference in the calibration of the value of g^{tr}/y in the benchmark simulations of the two models, which here is equal to 4.1%, rather than the 1.76% used in the earlier study.[42]

It is also important to note that the simulations in Table 1.2 are expansionary policy exercises (reduction of tax rates and increases in government expenditures), but the corresponding contractionary policies, whose effects are the *negative* of those displayed in the columns of that table for each policy, must also be considered. The following discussion refers to the policies themselves by "#" followed by its column number and to the respective symmetric policies by attaching an "N" to it. Therefore, the policy that has the largest effect in a given variable is the one that has the largest absolute value in the respective line of Table 1.2.

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[42] The transfers to households (g^{tr}) are take up the "slack" in the calibration to produce a virtual steady state, and the several differences in the specification and calibration of the current model from the model in Tourinho and Brum (2020) cause these differences in the calibrated value of this fiscal variable.

Table 1.2 – Steady State Effects of Changes in Fiscal Mix (*)

Simulation	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16	#17
Policy (&)	τ^l Reduction			τ^k Reduction			τ^c Reduction			g^c Increase				g^i Increase			
Compensation	g^{tr}	τ^c	τ^k	g^{tr}	τ^c	τ^l	g^{tr}	τ^l	τ^k	g^{tr}	τ^c	τ^l	τ^k	g^{tr}	τ^c	τ^l	τ^k
Δ Instrument (+)	-15.240	1.319	3.930	-12.619	0.985	1.204	-17.906	1.912	4.672	-21.943	1.969	2.401	5.917	-13.159	1.155	1.407	3.441
y	1.123	0.485	-0.917	1.456	0.974	0.593	0.763	-0.598	-1.661	0.785	-0.153	-0.910	-2.274	1.963	1.403	0.959	0.174
c	1.530	0.661	-0.403	1.358	0.704	0.187	1.040	-0.815	-1.261	-0.492	-1.770	-2.802	-3.395	1.114	0.350	-0.254	-0.575
c^R	1.930	0.531	-0.868	2.002	0.948	0.530	1.674	-0.659	-1.664	0.270	-1.775	-2.614	-3.902	1.621	0.396	-0.092	-0.825
c^{NR}	0.373	1.038	0.945	-0.506	-0.003	-0.808	-0.796	-1.267	-0.096	-2.698	-1.755	-3.344	-1.926	-0.354	0.215	-0.724	0.148
h	1.181	0.510	0.964	0.169	-0.332	-0.727	0.803	-0.629	0.545	0.826	-0.161	-0.957	0.529	0.648	0.065	-0.394	0.467
h^R	0.884	0.624	1.384	-0.358	-0.550	-1.033	0.309	-0.767	0.914	0.318	-0.062	-1.031	1.098	0.250	0.025	-0.536	0.695
h^{NR}	1.762	0.289	0.152	1.199	0.092	-0.132	1.769	-0.361	-0.166	1.819	-0.351	-0.814	-0.568	1.425	0.143	-0.118	0.024
i	1.123	0.485	-4.299	3.956	3.462	3.071	0.763	-0.598	-5.660	0.785	-0.153	-0.910	-7.325	1.963	1.403	0.959	-2.815
k	1.123	0.485	-4.299	3.956	3.462	3.071	0.763	-0.598	-5.660	0.785	-0.153	-0.910	-7.325	1.963	1.403	0.959	-2.815
w	-0.058	-0.025	-1.863	1.285	1.310	1.330	-0.039	0.031	-2.194	-0.040	0.008	0.047	-2.788	1.307	1.336	1.359	-0.291
w^R	0.237	-0.138	-2.270	1.820	1.532	1.642	0.453	0.170	-2.551	0.466	-0.090	0.122	-3.335	1.710	1.377	1.504	-0.518
w^{NR}	-0.627	0.195	-1.068	0.253	0.881	0.726	-0.988	-0.238	-1.497	-1.016	0.199	-0.097	-1.716	0.531	1.257	1.079	0.150
r^k	0.000	0.000	3.534	-2.405	-2.405	-2.405	0.000	0.000	4.239	0.000	0.000	0.000	5.450	0.000	0.000	0.000	3.075
ξ^R	1.401	0.173	-1.626	2.181	1.247	1.106	1.477	-0.224	-2.146	0.150	-1.656	-1.956	-4.383	1.458	0.377	0.210	-1.201
ξ^{NR}	-1.034	0.729	0.752	-1.396	-0.075	-0.642	-2.101	-0.889	0.042	-3.481	-0.954	-2.071	-0.945	-1.433	0.086	-0.575	0.117
ξ (**)	-0.304	0.562	0.039	-0.323	0.322	-0.118	-1.028	-0.690	-0.614	-2.392	-1.165	-2.037	-1.976	-0.566	0.173	-0.340	-0.278

Notes:

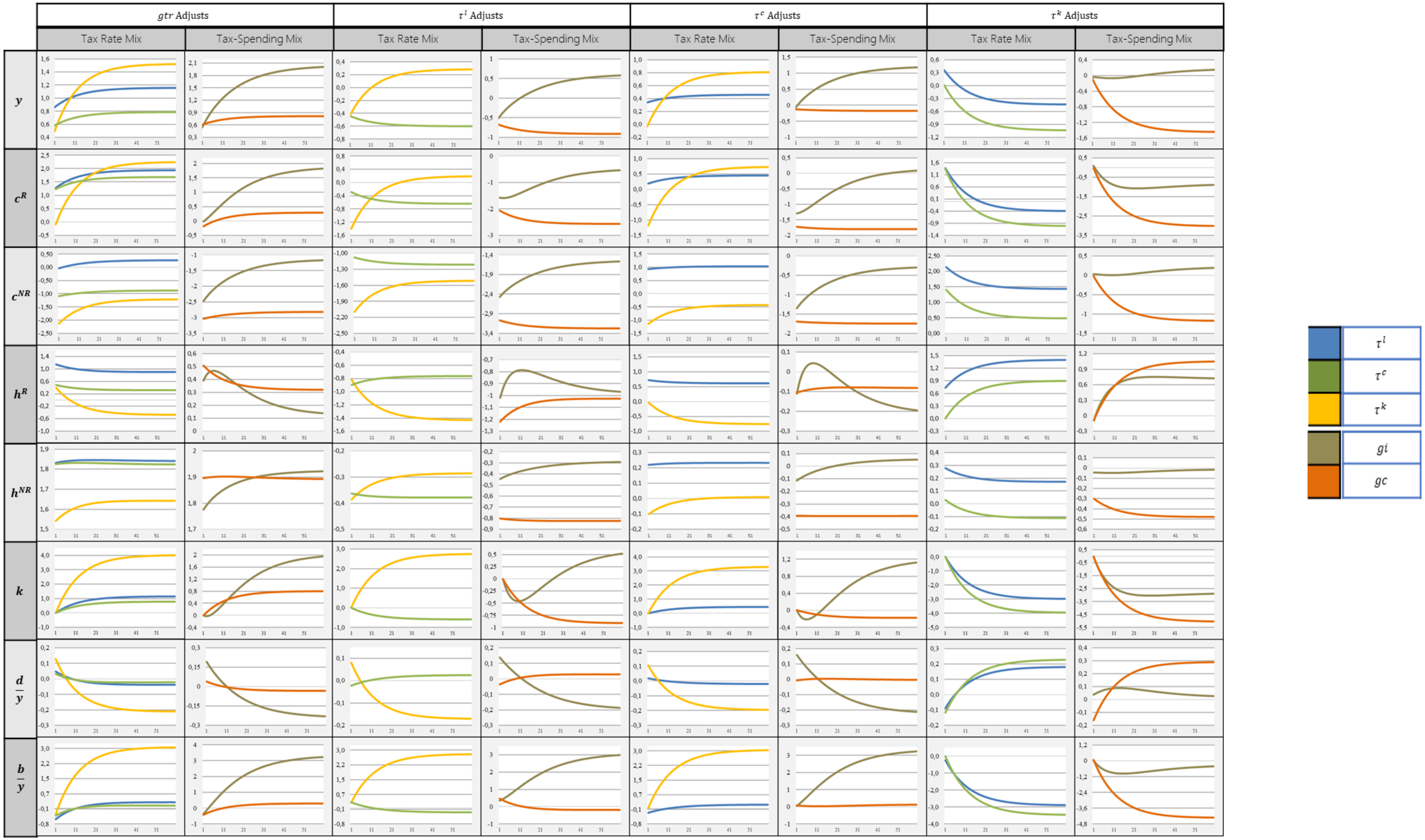
(*) The values in the table are in terms of percentage deviations in relation to pre-reform equilibrium with the exception of the tax rates, which are reported in p.p. (percentage points)

(&) The variation of the policy instrument is such that the value of the increase in revenue or reduction of expenditure is 1% of GDP at steady state.

(+) The variation of the offsetting instrument for the tax rates is shown in p.p. (percentage points), and for transfers it is in percentage change is the level relative to the steady state.

(**) Social welfare index: $\lambda\xi^{NR} + (1-\lambda)\xi^{R}$

Figure 1.1 – Dynamic Responses of Changes in Fiscal Mix (*)



(*) The graphs show *deviations* of the trajectory of the main variables in each case from that in the benchmark simulation.

1.5.1.1 Best policies to increase steady-state (SS) output

The policy that has the largest positive on effect output (2.3%) is #13N, where a 5.9 p.p. reduction in the capital income tax rate (τ^k) compensates a reduction of government consumption (g^c) equal to 1% of y. The second-best policy for y is #14, where an increase in government investment (g^i) equal to 1% of y is financed by a 13% reduction in government transfers to households (g^{tr}). However, the short- and medium-term effects are stronger in #14 than #13N. This can be seen comparing the trajectories for these policies in Figure 1.1, where #13N corresponds to the *symmetric* of the trajectory shown in the orange curve in the last column, and #14 corresponds to the dark green curve in column two. The effects on the other macroeconomic aggregates of these two policies are compared below.

Since the compensatory variation keeps the SS budget balanced, the effect on the SS deficit is null, and that variable does not appear in Table 1.2. However, the changes in the fiscal parameters will lead to deviations of the dynamic trajectory of the ratio of the budget deficit to output (d/y) from the benchmark, as shown in the corresponding line of Figure 1.1, due to the effects of the policy on the endogenous variables. For #14 and #13N they are positive and decreasing in the short run (for about 10 years), and negative and increasing in absolute value in the longer horizon. This means that the short-run deterioration of the budget these expansionary fiscal policies leads to an increase in the public debt-to-output ratio, as shown in line b/y in Figure 1.1. It should be noted however, that this is a general equilibrium effect, and that the trajectory of b_t is affected by several other parameters and variables of the model (see equations (1.32) and (1.33)) and, particularly, in #13N it is affected by the reduction in τ^k, and in #14 it responds to the increase in the return to private capital.

These two policies are also the best policies for y in the representative household model, and the magnitude of their effect in the two models is similar, but the compensatory changes of the instruments are different. In the present model, the required $\Delta\tau^k$ in #13N is 1 p.p. larger, and the required Δg^{tr} in #14 is about 70% smaller than in the earlier model.

The last two rows of Table 1.2 show the welfare index for the Ricardian and non-Ricardian households for all policies, respectively ξ^R and ξ^{NR}. While #13N increases the welfare of both types of households, by 4.4% and 1% respectively, #14 increases the welfare of the former by 1.5%, but decreases that of latter by 1.4%. Therefore, the benefits of the output increase accrue quite unevenly to the household types, favoring the Ricardian households. The reason is twofold: (i) the reduction of government consumption (g^c) and of transfers (g^{tr}) decrease the welfare of the non-Ricardian households more than of the Ricardian households and, (ii) only the latter benefit directly from the decrease in the tax rate on capital income (τ^k) or the increase in government investment $\left(g^i\right)$.[43] Since the fiscal mix changes that maximize log-run output do not favor the welfare of non-Ricardian households, they would not accept them unless the Ricardian households compensate (bribe) them with side-payments. The difference in the welfare index of these policies is a measure of size of the bribe required, in terms of the relative permanent increase in their consumption, and is equal to 3.4% and 3.1% for policies #13N and #14, respectively.

1.5.1.2 Best policies to increase steady-state (SS) consumption

Policy #13N, already described, yields the largest increase in aggregate private consumption (c), of about 3.4%, and the second-best policy from that perspective is #12N, which increases c by 2.8% by compensating a decrease of 1% of GDP in government consumption (g^c) with a reduction of 2.8 p.p. in the labor income tax rate (τ^l). These are also the best policies for c in the representative household version of the model, and their macro effects in the two models are similar. However, their effect on the consumption of the two types of households is quite different, and in #13N c_t^R and c_t^{NR} increase by 4% and 2% respectively, while in #12N they increase by 2.6% and 3.3% respectively. Further, the short run effects (which we will refer to as the *on impact* effect) are stronger in #12N than in #13N, as shown in the corresponding line of Figure 1.1.[44] Therefore, the Ricardian households would prefer #13N, while non-Ricardian households would prefer #12N. This is not surprising, since the magnitude of the decrease in g^c is the same in both policies, but the instrument and its compensatory variation are different in the two policies. In the former τ^k is reduced, which only benefits directly the Ricardian households, because only they have income from capital. In the latter

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[43] To see the reason for this effect, note that in equation (1.2) $\bar{G}_t^c$ is a relatively larger fraction of $C_t^{\hbar} + \vartheta\bar{G}_t^c$, and in equations (1.7) and (1.4) $\bar{G}_t^{tr}$ is a relatively larger part of household income, both for $\hbar = NR$ than for $\hbar = R$.

[44] One can ascertain the dynamic responses of policy #12N from its symmetric expansionary policy (#12), exhibited in the fourth column.

policy τ^l is reduced, which benefits the non-Ricardian households more, because most of their income is from labor.

The effect of policies #13N and #12N on consumption of the two types of households does not translate proportionately in their welfare indexes, ξ^R and ξ^{NR}. As indicated in the last section, for #13N to be accepted, the non-Ricardian households would require a bribe equivalent to a 3.4% increase of consumption forever. On the other hand, to agree to the adoption of #12N, they would not require any compensation, since $\xi^R = \xi^{NR} = 2\%$. Although these two policies are equivalent in terms of the aggregate social welfare index ($\xi \cong 2\%$), it is clear that #12N is preferable because it avoids the need for the side-payment.

1.5.1.3 Best policies to increase SS welfare

The best policy from the point of view of aggregate welfare is #10N, with $\xi = 2.4\%$, where a decrease in government consumption (g^c) equal to 1% of GDP is compensated by a 22% increase in transfers (g^{tr}), [45] and policies #12N and #13N with $\xi \cong 2\%$ are close second best. The disaggregation of the welfare change in the first best policy #10N indicates a large increase for the non-Ricardian households ($\xi^{NR} = 3.5\%$) which is more than sufficient to compensate the loss of the Ricardian households ($\xi^R = -0.15\%$). This asymmetric effect is not surprising, because that policy involves trading off public consumption, which affects equally the two types of households, for private consumption of the Non-Ricardian households to whom transfers accrue (see equation (1.7)). [46] The best policy for increasing the welfare of the Ricardian households is #13N ($\xi^R = 4.4\%$), which substantially increases their consumption of goods and leisure in the long-run, but is not so desirable for the non Ricardian households ($\xi^{NR} \cong 1.0\%$). Again, the households groups do not agree on the best policy.

The *symmetric* of orange colored trajectories in the second column of Figure 1.1 represents the dynamic behavior of the endogenous variables in policy #10N. The one for the non-Ricardian households' consumption (c^{NR}) shows a powerful positive impact, in spite of

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[45] The best policy for welfare in the representative household version of the model of Tourinho and Brum (2020) is the equivalent of #13N, with a significanly smaller a welfare index of 0.83%. The difference in the result of the models is most likely due to the previously indicated difference in the calibration.

[46] Using a somewhat different approach, Coenen and Straub (2005) find similar response pattern of private consumption to a government spending shock.

allowing an immediate reduction in their labor supply, because it substitutes transfers for wages, and since they are myopic consumption increases immediately.

The negative welfare effect of any policy for either household type is an indication of the resistance to its adoption. For the non-Ricardian households any policy that reduces the current income, be it by reducing transfers (g^{tr}) (#1, #4, #7, #10, #14) or raising the tax rate on labor income (τ^{l}) (#2N, #3N, #6, #8, #12, #16) represents a welfare loss. For the Ricardian households any policy that increases the tax rate on private capital (τ^{k}) (#3, 4N, #5N, #6N, #13, #17) reduces their welfare.

1.5.1.4 Effects on labor, capital, wages and returns to capital

One can trace back to the equations some of the effects in the variables shown in the simulations. For example, in #13N that produces the largest change in output $(\Delta y = 2.3\%)$ the aggregate number of hours in production (h) decreases by 0.5%, which is the net effect of an increase of 0.6% in h^{NR} and a decrease of 1.1% in h^{R}. These effects are consistent with the increase in leisure and of welfare of Ricardian households afforded by the reduction of the taxation of capital income. For the same reason, private capital stock (k) and investment (i) increase by 7.3%, which is the largest change of these variables among the policies considered here.[47] Furthermore, since there is no change in the public capital stock, the effect on y is the result of these increments in the private factors only. Given that the production function is C-D (equation (1.9)), it is possible to double-check in an approximate manner that effect on output using Euler's property of homogeneous functions: $\Delta y/\mathrm{y} \cong \alpha_1(\Delta k/k) + \alpha_2(\Delta h/h) = 0.35 \cdot 7.3\% + 0.62 \cdot (-0.5\%) = 2.25\%$.

Also, in #13N, the aggregate wage (w) increases 2.8% which is the largest change in w among policies considered in this section. [48] However, it accrues unevenly to the two types of households, since Δw is the weighted average of $\Delta w^{R} = 3.3\%$ and $\Delta w^{R} = 1.7\%$ (equation (1.14)). The effect of these changes in the disaggregated labor demand and supply are of opposite signs, due to the lower marginal productivity of labor of the non-Ricardian households

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[47] The changes in k and i are equal because there is a linear relation between these variables (equation (1.34)), so the percentage change must be the same.

[48] Because the technology is C-D, the prices of factors are proportional to their average product (equations (1.10) and (1.11)).

(equation (1.15)). Policies #3N and #9N, which also decrease the capital income tax rate (τ^k) and thereby increase the relative value of labor, also have a significant positive effect on w (approximately 2%). However, several fiscal mix changes which affect mainly the demand side of the economy have virtually no effect on aggregate wages, i.e. $|\Delta w| < 0.5\%$ for policies #2, #7, #8, #10, #11, #12.

Policy #13N also displays the largest reduction (-5.5%) of the rate of return to capital (r^k), because it increases k proportionately more than y, decreasing the average and the marginal product of private capital. Note also that the policies that use instruments related to the demand side of the economy (#1, #2. #7, #8, #10, #11, #12, #14, #15, #16) do not affect r^k.

1.5.2 Dynamic debt consolidation policies

This section considers debt consolidation policies that use a single instrument and divide the time horizon into two sub periods. In the first one, the *adjustment*, the value (constant) of the instrument is set to reduce the public debt through contractionary fiscal policy, and in the second sub-period, the *stabilization*, it takes another (constant) value to reach that reduced debt level at the terminal date. The simulations here assume that the adjustment sub-period lasts for 10 years (t = 0, 1, ... ,10) and that its target is a 10% reduction of in the level of the public debt, and that stabilization sub period lasts until the end of the horizon (t = 11, …, 180). The model calculates endogenously the values of the fiscal instrument in both sub-periods.

The fiscal instruments are $\tau_t^{LR}, \tau_t^{LNR}, \tau_t^c, \tau_t^k, g_t^i$ and g_t^c, for the policies labeled #18 to #23 in Table 1.3. [49] For each of them there are two columns, displaying the immediate impact (at t = 1) and the long-run effect (at t =60), [50] with the values in the cells displaying deviations of the endogenous variables with respect to their SS value in percentage points (p.p.) for b/y and d/y, and as the percentage change times 100 for the other variables. The changes in the instruments with respect to the SS value in each phase of the policy appear as the pair of lines labeled "Δ Instrument". For all policies, except #19, $\tau_t^{LR} = \tau_t^{LNR} = \tau_t^l$. Policy #19 simulates the case where the burden of the adjustment falls on the Ricardian households, and

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[49] Government transfers g_t^{tr} are not considered here due of their limited general equilibrim implications.

[50] Although the horizon is t = 180, by t = 60 most of the effect has been reflected in the solution of the model.

in the adjustment phase varies only τ_t^{LR} and maintains τ_t^{LNR} at its initial level, but in the stabilization phase adjusts both equally ($\tau_t^{LR} = \tau_t^{LNR}$).

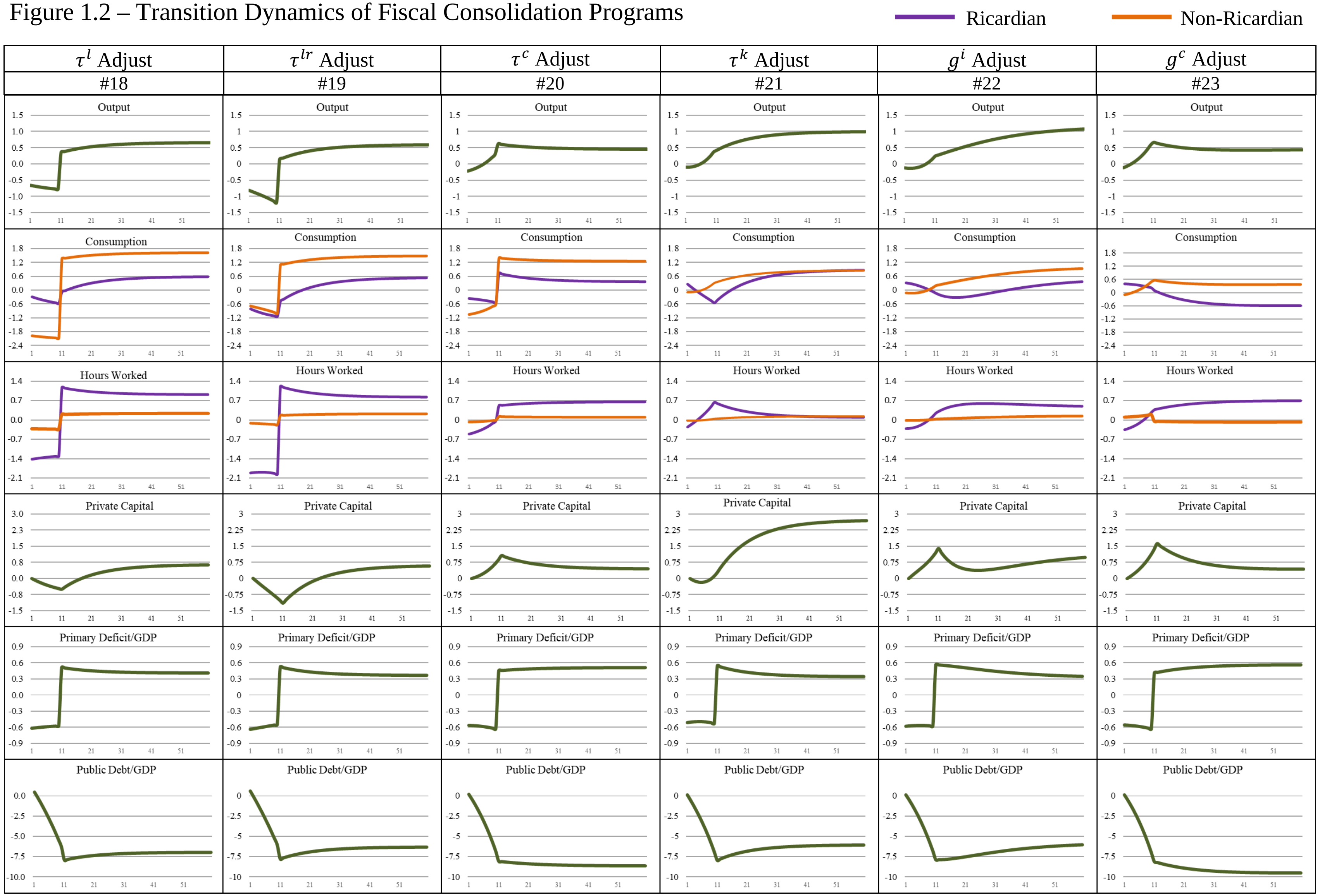
Figure 1.2 displays the dynamic paths of the main variables for each policy and shows that in most scenarios the policy impact (at $t = 1$) for the majority of variables is not representative of its behavior throughout the adjustment phase. Their overall shape varies significantly across policies, except for the fiscal variables, which are similar by design.

Table 1.3 - Impact and Long-run Effect of Fiscal Consolidations (*)

Policy	#18		#19		#20		#21		#22		#23	
Instrument →	$\tau_t^{l_R} = \tau_t^{l_{NR}} = \tau_t^{l}$ In both phases		τ^{l_R} in adjustment τ^{l} in stabilization		τ^{c}		τ^{k}		g^{i}		g^{c}	
Δ Instrument (*):												
Adjustment→	1,304		2,114		1,042		1,754		-17,585		-2,364	
Stabilization →	-0,973		-0,884		-1,011		-2,002		17,944		2,777	
Horizon	Impact	Long-Run	Impact	Long-Run	Impact	Long-Run	Impact	Long-Run	Impact	Long-Run	Impact	Long-Run
$\boldsymbol{y}$	-0.655	0.648	-0.816	0.587	-0.228	0.449	-0.107	0.989	-0.128	1.083	-0.121	0.439
$\boldsymbol{c}$	-0.722	0.847	-0.781	0.766	-0.542	0.590	0.169	0.859	0.202	0.503	0.280	-0.343
$\boldsymbol{c^{R}}$	-0.297	0.582	-0.810	0.525	-0.366	0.367	0.257	0.864	0.307	0.359	0.411	-0.588
$\boldsymbol{c^{NR}}$	-1.972	1.625	-0.697	1.474	-1.061	1.244	-0.091	0.846	-0.109	0.927	-0.104	0.375
$\boldsymbol{h}$	-1.050	0.689	-1.308	0.627	-0.367	0.469	-0.171	0.106	-0.205	0.383	-0.195	0.429
$\boldsymbol{h^{R}}$	-1.427	0.918	-1.920	0.836	-0.517	0.658	-0.252	0.094	-0.302	0.507	-0.348	0.691
$\boldsymbol{h^{NR}}$	-0.316	0.247	-0.110	0.224	-0.075	0.101	-0.014	0.130	-0.017	0.142	0.102	-0.079
$\boldsymbol{i}$	-1.233	0.659	-2.028	0.602	0.774	0.443	-1.389	2.733	2.057	1.136	1.536	0.435
$\boldsymbol{k}$	0.000	0.635	0.000	0.569	0.000	0.455	0.000	2.692	0.000	0.976	0.000	0.435
$\boldsymbol{w}$	0.400	-0.041	0.499	-0.040	0.139	-0.020	0.065	0.882	0.078	0.697	0.074	0.010
$\boldsymbol{w^{R}}$	0.783	-0.266	1.125	-0.247	0.290	-0.208	0.146	0.894	0.175	0.573	0.227	-0.251
$\boldsymbol{w^{NR}}$	-0.340	0.401	-0.707	0.362	-0.154	0.348	-0.092	0.858	-0.111	0.940	-0.224	0.519
$\boldsymbol{r^{k}}$	-0.655	0.013	-0.816	0.018	-0.228	-0.006	-0.107	-1.659	-0.128	0.105	-0.121	0.004
$\boldsymbol{b/y}$	0.442	-6.978	0.552	-6.344	0.154	-8.657	0.072	-6.093	0.086	-6.033	0.082	-9.520
$\boldsymbol{d/y}$	-0.613	0.406	-0.636	0.369	-0.563	0.509	-0.509	0.346	-0.580	0.349	-0.554	0.562
$\boldsymbol{\xi^{R}}$	0.005		-0.208		-0.018		-0.019		-0.095		-0.111	
$\boldsymbol{\xi^{NR}}$	-0.157		0.219		0.191		0.268		0.183		0.260	
$\boldsymbol{\xi}$	-0.108		0.091		0.128		0.182		0.100		0.149	

Notes: (*) The values are displayed in terms of percentage deviations in relation to pre-reform equilibrium – the exception is the primary deficit in terms of GDP and the tax rates, which are reported in p.p. (percentage points). A positive change in the primary deficit/GDP ratio means that the primary result deteriorated in comparison to the pre-reform equilibrium.

Figure 1.2 – Transition Dynamics of Fiscal Consolidation Programs



Notes: 1) The data are percentage deviations in relation to pre-reform equilibrium – the exception is the primary deficit in terms of GDP, which are reported in percentage points; 2) Each column shows the change in the trajectory of the variables of the policy using the fiscal instrument transition shown at its top; 3) A positive change in the primary deficit/GDP ratio means that the primary result has deteriorated in comparison to the pre-reform equilibrium

1.5.2.1 Effects on output

The comparison of the long-run effect on output of the policies in Table 1.3 indicates that #22 is the one that produces the largest increase (1.1%). Its instrument is government investment $\left(g^i\right)$, which is reduced by 17.6% in the adjustment phase, and increased by 18% in the stabilization.[51] The one that produces the second largest increase (1%) is #21, that uses as instrument the capital income tax rate (τ^k), which increases by 1.75 p.p. in the adjustment phase, and reduces by 2 p.p. in the stabilization phase. The immediate impact on output for both policies is small (-0.11%), but in #21 the recovery in the stabilization phase is faster (Figure 1.2). This is due to the effect of a smaller tax rate on capital income in private investment (i) and in the accumulation of private capital stock (k), which increase by 2.7% in the long run.

Policies #18 and #19, based on the labor income tax rates $(\tau_t^{LR}, \tau_t^{LNR})$ have similar smaller effects on long-run output (0.65% and 0.6%, respectively) than the ones above. The immediate negative impact of #19 and #18 (-0.82% and -0.66%, respectively) are much larger in absolute value than that of all other policies and persists throughout the adjustment phase (Figure 1.2). The subsection below on the labor market effects discusses them in more detail. The effect of these policies on y is essentially flat in the adjustment phase, propagating the immediate impact, but the stabilization phase reverses that loss very early.

The worse policies for y are #20 and #23, based on τ^c and g^c respectively, that increase long-run output by about 0.45%. As Figure 1.2 shows, their effect is hump-shaped, with a sharp increase in the adjustment phase followed by a progressive loss of this gain in the stabilization phase. This outcome is not surprising, because these demand side instruments that are less suited to increase long run output.

The long run effect on output of these debt consolidation policies is about half of the fiscal mix changes. For example, the largest effects in Tables 1.2 and 1.3 are 2.2% for #13N, and 1.1% for #22.

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[51] The slower growth of the government capital stock during the adjustment phase delays the recovery from the fiscal shock, but that effect is reversed in the stabilization phase. As indicated earlier, for this instrument the changes in the level are high because $g^i/y = 3.22\%$ in the SS, so large changes in the level are required to obtain a large enough reduction of the government deficit (d) to reduce the government debt (b) by 10% at the end of the adjustment.

The comparison of the output effects in Table 1.3 with those in the corresponding table of the representative household model indicates that, on average, their (negative) impact is 27% larger (in absolute value), and that their long run effect is 14% smaller. However, the ranking of the policies based on the long-run effect is the same in the two versions of the model. [52]

1.5.2.2 Effects on consumption

Policies #18 and #21 are the ones that produce the largest increase in long run aggregate consumption (c), approximately 0.85% for both of them. Their effect, however, is different for the two households. For #18, c^{NR} and c^{R} increase by, respectively, 1.6% ad 0.6%, while for #21 the increase in both is of the same magnitude (0.86%). The short run impact of these policies is also quite different. For #18 it is large and negative (-0.72%) and persists throughout the adjustment, while for #21 it is positive and small (0.17%) and becomes progressively more negative throughout the adjustment (Figure 1.2).[53]

The second largest increase in long run c is 0.77%, for #19, whose immediate impact is large and negative (-0.78%) and persists throughout that phase. In third place come #20 and #22, whose long run effect in c is respectively, 0.59% and 0.5%. The immediate impact in c of these policies is also quite different: for #20 it is negative and large (-0.54%) and persists throughout stabilization, while for #22 it is positive and small (0.2%), turns increasingly negative in the adjustment phase, but becomes positive and increasing in the stabilization phase.

Policy #23, which uses government consumption (g^{c}) as instrument, is the only policy that produces a negative effect on long run aggregate consumption (-0.34%). This is the result of effects of opposite signs for the two household types: 0.38% and -0.58% for c^{NR} and c^{R}, respectively. It is a consequence of the fact that the positive effect on the consumption of non-Ricardian households is insufficient to produce a positive aggregate

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[52] The comparison excludes #19 because there is no similar policy in the previous model.

[53] This is one example where the "impact" effect in Table 1.3 is not representative of the average effect in the adjustment phase.

effect, in spite of their large proportion in the population ($\lambda = 0.70$), because the wealthier Ricardian households, that suffer a negative impact, have a larger share of total consumption. The immediate impact in c is positive (0.28%), but that effect is illusory, because it is declining and eventually reverses in sign during stabilization. This shows that the short-run expansionary impact of increasing the government consumption is not sustainable in the long run in the context of an economy that is operating at full employment, and where the government has to satisfy an intertemporal budget constraint.

The policies that produce the largest long-run increase in consumption of each the two household types are distinct. For the Ricardian households #21 increases c^R by 0.86%, while policies #18 and #19 are second best for them, with increases of the order of 0.5%. For the non-Ricardian households, the best is #18, which increases c^{NR} by 1.6%, and the second best is #19, which increases it by 1.4%.

The immediate impact on the consumption of non-Ricardian households (c^{NR}) of all policies is negative, and for Ricardian households (c^R) it is negative for #18, #19 and #20, and positive for #21, #22 and #23. The impact of the contractionary fiscal policy on consumption in the adjustment phase is 4 times larger for the non-Ricardian than for the Ricardian households, due to the inability of the former to borrow to smooth consumption.[54] The aggregate consequence of this is similar to the decrease in the propensity to save in the representative household economy.

1.5.2.3 Effects on labor

The policies that have largest effects on aggregate labor demand and supply (h), both in the long run and on impact, are #18 (0.69% and -1%, respectively) and #19 (0.63% and -1.3%, respectively), which use the tax rates on labor income as instruments. These result from the aggregation of changes in the labor supply of each household type, h^R and h^{NR}, as indicated by equation (1.43). The changes for #18 are, respectively, 0.92% and 0.25% in the long run, and -1.43% and -0.32% on impact. For #19 they are, respectively,

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[54] This can be seen by comparing the c^R and c^{NR} lines in Table 1.3.

0.86% and 0.23% in the long run, and -1.92% and -0.1% on impact. Figure 1.2 shows that the change on impact lasts throughout the stabilization phase for both these policies.

Recall that in #18 the labor income tax rates of the two households are kept equal in both phases of the consolidation program ($\tau^{LR}= \tau^{LNR}$), and increase by 1.3 p.p. in the adjustment phase, and reduce by 1 p.p. the stabilization phase. Since this tax discourages work, as can be seen in equations (1.22) and (1.23), both households reduce their effort in the short run. In #18 the reduction of both taxes in the stabilization phase increases h^R and h^{NR}. However, in #19 the only instrument in the adjustment phase is τ^{LR}, which increases 2.1 p.p.. In the stabilization phase, $\tau^{LR} = \tau^{LNR}$ decline by 0.9 p.p. with respect to their values in the steady state. The differences between #18 and #19 in terms of their effects are mostly because in #19 the stabilization effort falls entirely to the Ricardian households, which are responsible for the savings and investment decisions in this economy.

For #18 the effect in aggregate labor (h) is a result of larger changes in h^{NR} than in h^R, as shown in Figure 1.2. This asymmetry in effort is due to the dependence of non-Ricardian households on net labor income, and the fact that Ricardian households have capital income. This also explains why the immediate impact of #18 on consumption is asymmetric: c^{NR} and c^R decline by 2% and 0.3%, respectively. This difference on impact lasts throughout the stabilization phase, and in long-run, when there is an increase in the hours worked and in consumption of both households.

Wages of the two types of labor reflect their relative scarcity in #18: on impact w^R increases by 0.8%, while w^{NR} decreases by 0.34%. In the long run these effects change substantially: w^R decreases by 2.7%, while w^{NR} increases by 0.4%.

1.5.2.4 Effects on private investment and capital stock

Policy #21, based on the capital income tax rate (τ^k), produces the largest increase (2.7%) in long run private investment (i) and private capital stock (k). This effect in k occurs in spite of a negative immediate negative impact in i (-1.4%) which lasts throughout most of the adjustment phase, as shown in Figure 1.2. However, since

$\Delta k/\Delta y = 1.7$, the average product of capital increases, and the long-run interest rate (r^k) declines by 1.66%. This is the only policy where r^k changes significantly.

Policies #18 and #19, discussed in the previous section, increase long run private investment by 0.66% and 0.60%, respectively, and capital stock by 0.64% and 0.57%, respectively. They are, therefore, a very distant second best from that perspective. Since their immediate negative impact on private investment is of the same order of magnitude as that of #21 (-1.2% and -2%, respectively), they are clearly inferior.

Policy #20, which uses τ^c as its instrument, yields some peculiar results with respect to i and k. The long run change in those variables is 0.45%, only 20% smaller than the change obtained with #18 and #19, but it is the only tax-based consolidation policy that has a positive impact on investment (0.77%). The long-run average product of capital ends up at same level as that in the SS, and consequently, there is no change in the long-run interest rate (r^k).

1.5.2.5 Effects on public capital stock

The only policy that affects the public capital stock (k^g) is #22,[55] which uses public investment $\left(g^i\right)$ as instrument. The changes in that instrument are -17.6% during the adjustment, and 17.9% in the stabilization, relative to the SS values, and the change in long run k^g is of the same magnitude as that of g^i, due to equation (1.41).

Using the Euler property of homogeneous functions,[56] the change in y is approximately the value read of Table 1.3: $\Delta y/y \cong \alpha_1(\Delta k/k) + \alpha_2(\Delta h/h) + \alpha_3(\Delta k^g/k^g) = 0.35 \cdot 0.976\% + 0.62 \cdot 0.383\% + 0.03 \cdot 17.94\% = 1.1\%$. It is interesting to note in the parcels of this sum that, in spite of the small elasticity of output with respect to public capital (α_3 =3%), the increase in k^g is responsible for about half of the effect, due to the large relative increase in the public capital stock (k^g). However, this powerful long run instrument has a small short-run impact on for output, only -0.13%, because in the adjustment phase the reduction of public investment "uncrowds" private investment.

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[55] One may also recall that #22 is the policy that displays the largest increase in long-run output.

[56] This study used that same procedure in section 4.1.2 to approximate the effects of policy #13N.

1.5.2.6 Effects on public debt and deficit

For all policies, and #20 in particular, the reduction of the primary deficit in the adjustment phase is necessary to achieve the debt target, and the subsequent increase in the stabilization phase is possible mainly because the lower public debt level reduces the interest payments. The reduction of d/y is also approximately constant in the stabilization phase of all policies. The long run changes in the primary deficit-to-output ratio (d/y) in Table 1.3 ranges between 0.35 p.p. and 0.51 p.p., across policies, and the largest effect is for policy #20, which uses the interest rate on capital income (τ^k) as instrument. On impact d/y decreases by about 0.55 p.p. across all policies, and Figure 1.2 indicates that this effect persists throughout the stabilization phase, but at different levels: for policies #20 and #23 it is 0.5 p.p. while for the other policies it is about 0.35 p.p..

Across the several policies, the reduction of the public debt-to-output ratio (b/y) is between 6 p.p. and 9.5 p.p. at the end of the adjustment phase, after a small increase on immediate impact, as can be seen in Figure 1.2. This is consistent with the objective of reducing the level of debt (b) by 10% in the long term, because the effect of the policies on long-run output is different. Policies #21 and #22, which display the largest increase in y, are also the ones that produce the smallest decrease in that ratio. Policy #23 produces the smallest long-run increase in output, and the largest decrease in that ratio.

1.5.2.7 Welfare effects

The last lines of Table 1.3 show the effect of the different policies on the Ricardian and non-Ricardian households welfare index, respectively ξ^R and ξ^{NR}. For the Ricardian households the best policy is #18, with $\xi^R = 0$ i.e. it has no effect on their welfare. The second-best policies for them are #20 and #21, which have $\xi^R = -0.02$ %, and none of the policies have a strictly positive value for ξ^R. For the non-Ricardian households, the best policy is #21, with $\xi^{NR} = 0.27$ %, and #23 is a close second best, $\xi^{NR} = 0.26$ %, and all policies have positive ξ^{NR}, except #18. Therefore, none of the policies has a positive index for both households, and there is no Pareto optimal policy.

The impasse is clear: the only policy acceptable to the Ricardian households is unacceptable to the non-Ricardian households, and none of the acceptable policies to the latter is acceptable by the former. The ranking of the instruments according to the decreasing value of the welfare index of the corresponding policy is quite different for the two household types: for Ricardian households, $\tau^{L} \gtrsim \tau^{c} \gtrsim \tau^{k} \gtrsim g^{i} \gtrsim g^{c} \gtrsim \tau^{LR}$, and for non-Ricardian households, $\tau^{k} \gtrsim g^{c} \gtrsim \tau^{LR} \gtrsim \tau^{c} \gtrsim g^{i} \gtrsim \tau^{L}$. The fact that there is no common sub-ranking of policies shows that the disagreement goes much beyond the choice of most desirable policy instrument.

The ranking according to the social welfare index ξ defined by equation (1.47) can resolve the impasse, since it indicates the policy that would win the most votes in an election were each household would have one vote, with no coalitions or bribes allowed. In that case, the ranking of the instruments is $\tau^{k} \gtrsim \tau^{c} \gtrsim g^{c} \gtrsim g^{i} \gtrsim \tau^{l_R} \gtrsim \tau^{l}$, and policy #21 is the best. Not surprisingly, this is the policy that maximizes the long-run aggregate consumption and the welfare of the non-Ricardian households, and its social welfare index is equivalent to a 0.18% increase in the average per capita aggregate consumption in each year of the trajectory forever.

1.6 Concluding Remarks

This chapter evaluates different fiscal policies for debt consolidation using a dynamic general equilibrium model with heterogeneous households calibrated for the Brazilian economy. The households are distinguished by their access to financial markets (Ricardian and non-Ricardian) and consider two types of fiscal instruments: taxes and government expenditures. The former are: the tax rates on consumption, capital income, and labor income of the two household types, and the latter are: public consumption, public investment and transfers to households.

The simulations this chapter are of two types: fiscal mix changes and debt consolidation exercises. The former compares the effects of a change in a fiscal instrument compensated by a change in another instrument to keep the steady state public debt unaltered, with the initial change calibrated to correspond to a fiscal effort equal to 1% of GDP to make them comparable. The debt consolidation simulations use a single instrument to first reduce the public debt by of 10% in 10 years, and then stabilize it at this new lower level. The numerical solution calculates endogenously the value of the instrument in the adjustment period to achieve the desired public debt reduction, and the level in the stabilization phase to preserve that reduction at the terminal debt. The fiscal policies are compared in the context of the applied model, so the conclusions are contingent on the specification of the model and, particularly, on its calibration to the Brazilian economy in 2016.

The fiscal mix change that yields the largest increase in output (2.3%) is the reduction of the tax rate on capital income financed by a decrease of government consumption. The second-best policy from that perspective is the increase of public investment financed by a decrease in government transfers to households. The former is also the best policy for increasing aggregate consumption, but the second-best policy for that purpose is to reduce government consumption and use the resulting fiscal slack to reduce the tax rate on labor. The effect of these last two policies in the consumption of the two household types is asymmetric. The increase in consumption of Ricardian households of the first policy is 50% larger than that of the second. On the other hand, the increase of the consumption of non-Ricardian households of the second policy is 74% larger than that of the first one.

The effect of the best policy for long-run output and consumption on welfare of the two households is equivalent to a permanent increase of 4.4% and 1%, in the consumption stream for the Ricardian and non-Ricardian households, respectively. The second-best policy for consumption, which is the one that reduces the labor income tax rate and the government's consumption, increases the welfare of the two household types in the same proportion (2%). Therefore, the former policy leads to a conflict between the two household types in the distribution of the gains of the policy, while the latter is neutral. The desire to avoid conflict across different income classes over the acceptance of the consolidation plan may suggest the choice of a second-best policy.

The conflict could be resolved by adopting the principle of maximizing a social welfare index equal to the weighted average of the welfare index of the two types of households, with weights equal to their proportion in the total population. From that perspective, the best policy is neither of the two in the previous paragraph, but is rather the reduction of government consumption, and use of the resulting fiscal slack to increase transfers to households. The effect of this policy in the welfare of the Ricardian households is null, but its effect on the non-Ricardian households in the equivalent of a 3.5% increase of in their consumption stream forever.

Only two of the seventeen possible combinations of the fiscal instruments yield an increase in the welfare of both households. They are the reduction of the tax rate on labor income financed by an increase of the consumption tax rate, and the increase in public investment compensated by an increase in tax rate on consumption, but the social welfare index of both these policies is very small.

The debt consolidation exercises reveal that the policy that yields the largest long run increase in output (1.1%) uses government investment as instrument, and the one that produces the second largest increase (1%) uses the tax rate on capital income as instrument. Their effects on aggregate consumption of these policies are equal to 0.5% and 0.86%, respectively, inverting the output-based ranking. Further, these policies affect the two households differently. For the first one the increase of consumption of the Ricardian and non-Ricardian households is, respectively, 0.5% and 0.35%, and for the second one it is equal to 0.86% for both.

The ranking of the instruments in terms of the effect they have on the social welfare index is $\tau^k \gtrsim \tau^c \gtrsim g^c \gtrsim g^i \gtrsim \tau^{LR} \gtrsim \tau^l$, i.e. the best instrument is the tax on capital income, and the worse is the tax on labor income when the rate is the same for both two household types $(\tau^l = \tau^{LR} = \tau^{LNR})$ in both phases of the consolidation. However, all policies that increase welfare for the non-Ricardian households decrease it for the Ricardian households, and vice versa. In fact, the only the debt consolidation policy that increases the welfare of the Ricardian households is the one based on the tax rate on labor income of both households.

In summary, with household heterogeneity with respect to access to the financial markets there may be strong disagreement with respect to the adoption any of the fiscal mix changes or debt consolidation plans examined here, and that explains at some extent why there is so much difficulty in their implementation in Brazil.

Moreover, the results refer ultimately to the importance of accessing the effects of a given fiscal policy through the perspectives of households from different income classes and suggest that adding features that allow, for example, economic mobility and financial frictions may be compelling extensions to the model. Furthermore, it would be valuable if future works compare the implications of these numerical simulations to available empirical evidence.

2 INEQUALITY AND GROWTH IN AN APPLIED DGE MODEL WITH HETEROGENEOUS AGENTS AND PROGRESSIVE TAXATION OF CAPITAL INCOME

2.1 Introduction

The interaction of economic growth and income inequality has been a topic of keen interest since seminal the study of Kuznets (1955), but there is significant controversy with regards to its nature, direction of causality, magnitude, and sign. The comparison of the findings of Alesina and Rodrik (1994), Persson and Tabellini (1994) and Perotti (1996), which found a negative effect, with those Li and Zou (1998), Forbes (2000) and Barro (2000), that do not find any effect, illustrates this. In addition, the conclusions of those studies cannot be easily extrapolated to the fiscal environment of modern economies because they consider flat-rate tax systems, not the progressive tax codes that are more prevalent in actual economies, as pointed out by Stokey and Rebelo (1991), Mendoza, Razin and Tesar (1994), Domeij and Heathcote (2004) and Garcia-Peñalosa and Turnovsky (2008, 2011). The recent surveys by Muinelo-Gallo and Roca-Sagalés (2013), and Heshmati and Kim (2014) also show this.

The recent literature extends earlier models by introducing progressive taxation and other features of present-day tax codes that may affect inequality, like nature of the structural change considered, the asset markets organization, and the design of the fiscal instruments. For example, Atolia, Chatterjee and Turnovsky (2012) show that a productivity increase induces a change in the growth–inequality tradeoff, and that a gradual productivity change leads to more long run wealth inequality.[57] Some studies specify models with incomplete markets, as Domeij and Heathcote (2001), Castañeda et al. (2003), Nishiyama and Smetters (2005), Conesa and Krueger (2006), Conesa et al. (2009) and Kitao (2010). Other strand of the literature, to which this study belongs, assumes the existence of complete markets, such as Sarte (1997), Heer and Trede (2003),

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[57] The interest in this issue has also been rekindled by studies in another strand of the literature that describe the evolution of income and wealth inequality over the long range (e.g., Piketty and Saez 2003; Davies et al. 2007).

Li and Sarte (2004), Carroll and Young (2009), Lehmus (2011), Angyridis (2015) and Koyuncu and Turnovsky (2016). Further, as discussed later, several of these studies consider different models of the fiscal instruments, which hinder their comparison.

Broadly speaking, the basic question the studies in this literature address is how redistributive tax systems affect long-term economic growth, as indicated in Caroll and Young (2011). [58] In general, they find that more progressivity reduces work incentives (e.g., Koyuncu, 2011), capital accumulation (e.g., Krueger and Ludwig, 2013; Guvenen, Kuruscu, and Ozkan, 2014), and economic growth, confirming the findings of earlier studies such as Hausman (1981), Blomquist (1983) and Blomquist, Eklöf, and Newey (2001). Nevertheless, they have not exhausted the range of possible characterizations of the behavior of households, disaggregation of household types, and policy formulations, so this study is an effort to contribute to literature by considering a set of novel relevant features. More broadly, it adds to the effort to incorporate heterogeneity of economic agents in the macroeconomic models in order to improve the accuracy of their results, even if the primary interest is not to study inequality, as indicated by Vines and Wills (2018).

The point of departure for the study in this chapter is Koyuncu and Turnovsky (2016), hereafter K&T, which discusses the effect of tax progressivity on economic growth and income inequality in an endogenous growth model with two household types distinguished by their rate of time preference. They find that increases in the income tax progressivity reduces the long-term level of inequality and the economic growth rate, so there is a negative tradeoff between equality and growth. They also describe the transitional dynamics of the economy to reach this long-term equilibrium. A crucial feature of their model is the elasticity of labor supply, which affects how production adjusts to the changes in the progressivity of the income taxation and leads to conclusions regarding the effects of fiscal policy that are different from those extracted from models with inelastic labor supply.[59]

This chapter makes several extensions of the analysis in K&T, as follows. First, it allows for different tax rates for capital and labor income, to address several issues related

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[58] Poterba (2007) describes the effects of tax policy on income inequality, and the Congressional Budget Office (CBO) (2007) provide detailed information on both before- and after-tax distribution of income.

[59] Bosi and Seegmuller (2010) indicate the importance of endogenous labor supply, for example. An example of model with progressive taxation and inelastic labor supply is Li and Sarte (2004), that expands on Sarte's (1997) earlier results by adopting the progressive tax code representation of Guo and Lansing (1998), where the tax rate is an increasing function of the agent’s relative income.

to current fiscal policy in the US that involve more intensive use of capital income and wealth taxation to finance public expenditures in social programs and income redistribution policies. It also specifies a progressive tax levied on each source of income, to assess the effects of a fiscal reform that eliminates the progressivity of the labor income tax. Second, it considers five household types instead of only two, to be able to account in more detail the effect of the changes in fiscal policy on the dynamic path of the income distribution. Third, it uses differences in the elasticity of intertemporal substitution (EIS) to characterize household heterogeneity, instead of differences in the rate of time preference. In spite of the added features, it is still possible to obtain a tractable model that yields a non-degenerate distribution of income and wealth. Further motivation and justification for these extensions follow.

There are two main reasons to consider five types of households in specifying and calibrating the model, each corresponding to the average household of a quintile of the income distribution. First, while in many countries it suffices to consider two income classes and a two-tier marginal tax rates schedule to describe the tax code, in other countries – like Sweden, France, Japan and Canada – the schedule is more progressive, and the range of marginal tax rates is broader, so more income classes are required to satisfactorily approximate it. [60] Additionally, even in the case of countries that whose tax system is not very progressive, it is necessary to consider more income classes to be able to analyze policy proposals that involve increased progressivity. This is the case of the recent discussion in the USA and several other countries regarding the increase of the marginal tax rate for the top income households. [61] The third reason for using a finer income disaggregation is to allow a more precise assessment of the transitional dynamics, as households climb the income distribution ladder.

The characterization of household heterogeneity through differences in the EIS of each income class is seldom used in the study of the effect of fiscal policy on the tradeoff between inequality and economic growth.[62] There are several reasons to adopt this

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[60] For example, Rubolino and Waldenström (2019) observe the distributional effects of progressive reductions implemented by several developed countries in the end of last century and conclude that the top 0.1 income percentile were the most benefited by these reforms.

[61] For example, Saez and Zucman (2019) investigate the effects of the increased taxation of top income percentiles, and Summers and Sarin (2019a,b) study the revenue that can be obtained with a wealth tax.

[62] This observation does not imply that macroeconomic models have not considered the effects of different values for the *aggregate* elasticity of intertemporal substitution. Its importance for the assessment of fiscal and monetary policies, and long-term economic growth and welfare, has been extensively studied (e.g. King and Rebelo 1990; Rebelo 1992; Easterly et al. 1994).

approach here. The main ones are that the EIS is a key parameter in determining the relation between steady state (SS) ratios and economic growth, as indicated by Attfield and Temple (2010), [63] and that there is ample empirical evidence on the variation of the EIS across income classes, supporting this characterization of heterogeneity. The literature amply documents this, as follows. Attanasio and Weber (1993) estimate the EIS considering that socio-demographic factors may vary across different cohorts and notice that not considering them may bias the measurements obtained from aggregate data. Chatterjee (1994) allows for the existence of a monotonic relationship between average propensity to save and wealth due to differences in the EIS and shows that they can influence the evolution of wealth inequality over time. Atkeson and Ogaki (1996) allow for differences in the EIS between rich and poor households, being smaller for the latter, because they spend a larger share of their budget in the consumption of subsistence and necessary goods which are harder to reallocate in time.[64] Further, by comparing the estimates of the rate of time preference and the EIS for different wealth and income levels, they conclude that the former appears to be constant, while that the latter varies significantly, being larger for the richer individuals.[65] One can infer the diversity of the EIS across households from the differences in the coefficient of relative risk aversion in stochastic models that use time-separable utility functions, and extract empirical estimates of the former from capital markets data, as in Wang (1996). In the light of this evidence, the model here considers that the average households of the quintiles of the income distribution have different EIS and concludes that in the long run the households that have higher willingness to substitute future for present consumption end up owning the largest fraction of the capital stock.

Jointly, these extensions help us capture macroeconomic effects that, among other insights, suggest that the degree of progressivity of the tax rate on capital income plays a

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[63] The importance of the EIS for the effect of fiscal policy in the long-run equilibrium in representative agent models is also pointed out by Summers (1982) and King and Rebelo (1990), among others.

[64] Using panel data from India, Atkeson and Ogaki (1996) consider six household types find that the EIS varies between 0.8 and 0.5, the values they find for the richest and poorest households, respectively.

[65] Vissing-Jørgensen (2002) observe that the access to financial markets also contributes to the differences among consumers' willingness to substitute consumption through time, since only those that hold a given asset have reasons to change their consumption growth rate due to variations in its return. His estimates of the EIS of agents that do not hold assets is close to zero, while for stockholders and for bondholders it is positive. Incorporating this feature to an RBC model, Guvenen (2006) considers an economy with two types of households, where the stockholders have higher EIS vis-à-vis the non-stockholders. The wealth inequality produced by such environment is one in which the high-elasticity agents own virtually all the capital stock in the economy, whereas consumption is more evenly distributed.

key role in the economy, that focusing on a two-sector economy provides an incomplete picture of the distributional effects of a given fiscal policy, and that the response to fiscal reforms varies widely across households due to differences in saving behaviors.

The chapter is organized as follows. Section 2 presents the specification of the model and section 3 discusses the equilibrium solution of the model and shows that households with higher EIS end up owning the largest fraction of the capital stock. Section 4 discusses the generic calibration of the model for a typical OECD economy, and section 5 shows the equilibrium for the benchmark case, and attempts to isolate the effects of the progressiveness in labor income taxation by simulating the effects of a fiscal reform that replaces the progressive rate with a flat rate for the labor income tax in order. Section 6 contains final considerations and conclusions.

2.2 Model Specification

The model used here is an adaptation and extension of the one in K&T. As indicated in the introduction, its specification is altered to consider households distinguished by their EIS rather than the rate of time preference, and postulates a fiscal function which allows different rates to be applied separately to labor and capital income, as Chen (2020). Nevertheless, the next section fully specifies the extended model used here, for completeness. The proposed changes produce significant changes in the equilibrium and dynamics of the model, when compared with K&T.

2.2.1 Production technology

There are J identical firms indexed by j that have a production function of the Romer (1986) type, which assumes there is a knowledge externality proportional to the aggregate capital stock. For simplicity, suppose its functional form is Cobb-Douglas:

$$Y_j = A(L_j K)^{\alpha} {K_j}^{1-\alpha} \tag{2.1}$$

where, there Y_j is the level of homogeneous output K_j is the private capital stock, L_j is the labor services input to production, K is the average aggregate capital stock in the economy, and A is the scale parameter. This production function is consistent with endogenous growth, since it displays constant returns of scale with respect to L_j and K_j, as well as to K_j and K. The term $L_j K$ is the labor input in efficiency units.[66] Since firms are supposed to be identical, $K_j = K$ and $L_j = L$, and the aggregate production function is a linear function of the average aggregate capital stock:

$$Y = AL^{\alpha}K. \tag{2.2}$$

The marginal physical products determine the equilibrium factor prices. Letting l denote the average economy-wide leisure time, so that $L = 1 - l$, the wage rate (w) and the return to capital (r) must satisfy the following equations

$$w = \alpha AL^{\alpha-1}K = \alpha A(1-l)^{\alpha-1}K \equiv \omega(l)K \tag{2.3}$$

$$r = (1-\alpha)AL^{\alpha}K^{\alpha}{K_j}^{-\alpha} = (1-\alpha)A(1-l)^{\alpha} \tag{2.4}$$

where $\omega(l) = \alpha A(1-l)^{\alpha-1}$ is the aggregate marginal productivity of labor, which is the return to "raw" labor.

2.2.2 Households

There are N households indexed by i, which are identical in all respects except for their EIS_i, and it is assumed that smaller absolute values of it imply the household is less willing to substitute future for present consumption. They are as distinguished by their initial endowments of capital $(K_{i,0})$, and of time (hours), which is normalized to be equal to one unit, and allocated to leisure (l_i) and work (L_i), so: $L_i = 1 - l_i$.

In addition, the model considers that the households have an infinite planning horizon and maximize the present value of utility discounted by the rate of time preference (β_i), and that their utility is an isoelastic function of an amalgam of consumption (C_i) and leisure:

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[66] See Barro and Sala-i-Martin (2004, p. 217) for further discussion of this formulation.

$$\max \int_0^\infty \frac{1}{\gamma_i} (C_{it} {l_{it}}^{\eta})^{\gamma_i} e^{\beta t} dt. \tag{2.5}$$

where $-\infty < \gamma_i < 1, \eta > 0, 1 > \gamma_i \cdot (1 + \eta)$ to ensure it is a concave function. Henceforth the index t will be omitted since it is implicit in these dynamic variables. For this function, $\mathrm{IES_i} = 1/(1 - \gamma_i)$, and $\mathrm{CRRA_i} = 1 - \gamma_i$. It is also important to note in (2.5) that the substitution between consumption and leisure does not display constant elasticity, in contrast with many models found in the literature, a fact that has important implications for the supply function of labor. The household's gross income is $Y_i = rK_i + \omega K(1 - l_i)$ and $Y = rK + \omega K(1 - l)$. The first term in the right-hand side is the capital income and the second is the income from "raw" labor, i.e. labor not augmented by the productivity increase due to an externality proportional to K.

The labor and capital income tax schedules are progressive, and their formulation is analogous to the one employed by Guo and Lansing (1998), Li and Sarte (2004), Lloyd-Braga et al. (2008) and K&T for total income, but here it is applied separately to each income source. For each household, the tax rate of each factor depends on the quantity supplied, relative to that of the average household, and the corresponding tax rates (τ_{L_i}) and (τ_{k_i}) are given by

$$\tau_{L_i} \equiv 1 - \zeta_L \left[\frac{(1 - l_i)}{(1 - l)}\right]^{-\phi_L} \tag{2.6a}$$

$$\tau_{k_i} \equiv 1 - \zeta_k (k_i)^{-\phi_k} \tag{2.6b}$$

where ζ_L and ζ_k are the levels of each tax schedule, while $\phi_L \geq 0$ and $\phi_k \geq 0$ are the degrees of progressivity of each tax schedule, and $k_i \equiv K_i/K$ is the share of the average physical capital for household i. Note that the schedules in (2.6a) and (2.6b) shift down with an increase of ζ_L and ζ_k, because they indicate the departure of these rates from their asymptotic value 1. Furthermore, assuming a positive degree of progressivity, the tax rate on labor income increases with relative labor supply, i.e., households that work more hours than the average will earn relatively more income from labor and, hence, their labor income will be taxed by a rate higher than the economy-wide tax rate. Similarly, the tax rate on capital income increases with relative capital owned by the household i. Note also for future reference that the average k_i is 1. This formulation can also accommodate a schedule without progressivity in the labor or the capital income tax by setting $\phi_L = 0$ or $\phi_K = 0$, respectively, and making them independent of the capital share or the relative labor hours of household i. The marginal rates, denoted ${\tau_{k}}_{i}^{m}$ and ${\tau_{L}}_{i}^{m}$, can be calculated from (2.6a) and (2.6b) as:

$$\tau_{L_i}{}^{m} \equiv \frac{\partial(\tau_{L_i}L_i)}{\partial L_i} = 1 - (1 - \phi_L)\,\zeta_L\,\left[\frac{(1-l_i)}{(1-l)}\right]^{-\phi_L} = \tau_{L_i} + \phi_L(1 - \tau_{L_i}) \tag{2.6c}$$

$$\tau_{k_i}{}^{m} \equiv \frac{\partial(\tau_{k_i}K_i)}{\partial K_i} = 1 - (1 - \phi_k)\,\zeta_k\,{k_i}^{-\phi_k} = \tau_{k_i} + \phi_k(1 - \tau_{k_i}) \tag{2.6d}$$

Note also that the implicit tax on the productivity augmenting knowledge is part of the capital income tax, because it is proportional to K and the labor tax applies to "raw" labor.[67]

Households choose the time path of consumption, leisure and the rate of capital accumulation to maximize discounted utility, subject to the state transition equation:[68]

$$\dot{K}_i = \left(1 - \tau_{k_i}\right)[rK_i] + \left(1 - \tau_{L_i}\right)[\omega K(1 - l_i)] - C_i - \delta K_i \tag{2.7}$$

The first-order conditions for the maximization of (2.5) subject to (2.7) are:

$${C_i}^{\gamma_i - 1}{l_i}^{\eta\gamma_i} = \lambda_i \tag{2.8a}$$

$$\eta {C_i}^{\gamma_i}{l_i}^{\eta\gamma_i - 1} = \left(1 - \tau_{L_i}{}^{m}\right)\omega K \lambda_i \tag{2.8b}$$

$$(1 - \tau_{k_i}{}^{m})\, r - \delta = \beta - \frac{\dot{\lambda}_i}{\lambda_i} \tag{2.8c}$$

where the co-state variable λ_i is the shadow value of capital of household i. Equation (2.8c) shows how the marginal income tax rate affects the growth rate of λ_i and, thereby, the household's decision to accumulate capital.

In addition to these marginal conditions, the optimal paths must satisfy the transversality condition.

$$\lim_{t\to\infty} \lambda_i\, K_i e^{-\beta_t} = 0 \tag{2.9}$$

As will be shown later, the long-run aggregate growth rate of capital and consumption will converge to a common value $\tilde{\psi}$, and (2.9) reduces to:

$$(1 - \tau_{k_i}{}^{m})\, r > \tilde{\psi} \tag{2.10}$$

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[67] Recall that the production function (2) considers a broad concept of capital, defining it as an amalgam of human and physical capital, and that income from labor is the payment for raw labor (L_i) and does not include the returns associated with skills, following Mankiw, Romer, and Weil (1992) and Barro, Mankiw, and Sala-i-Martin (1995), as indicated earlier.

[68] Here, and elsewhere in this chapter, the dot over a variable indicates its time derivative.

The aggregation rules of income, capital and leisure, and clearance of the aggregate labor and capital markets, are as follows:[69]

$$\left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(\frac{Y_i}{Y}\right) = 1 \qquad \left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(\frac{K_i}{K}\right) = 1 \qquad \left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(\frac{l_i}{l}\right) = 1 \tag{2.11a}$$

$$\left(\frac{1}{J}\right)\sum_{j=1}^{J} L_j = L = 1 - l = \left(\frac{1}{N}\right)\sum_{i=1}^{N}(1 - l_i) = \left(\frac{1}{N}\right)\sum_{i=1}^{N} L_i \tag{2.11b}$$

$$\left(\frac{1}{J}\right)\sum_{j=1}^{J} K_j = K = \left(\frac{1}{N}\right)\sum_{i=1}^{N} K_i \tag{2.11c}$$

The average and marginal tax rates are a weighted average of the individual rates, with their relative capital income as weights, as follows.

$$\bar{\tau}_k = \left(\frac{1}{N}\right)\sum_{i=1}^{N} \tau_{L_i} k_i \tag{2.12}$$

$$\bar{\tau}_k{}^m = \left(\frac{1}{N}\right)\sum_{i=1}^{N} \tau_{k_i}{}^m k_i \tag{2.12a}$$

$$\bar{\tau}_L = \left(\frac{1}{N}\right)\sum_{i=1}^{N} \tau_{L_i} \frac{(1 - l_i)}{(1 - l)} \tag{2.13}$$

$$\bar{\tau}_L{}^m = \left(\frac{1}{N}\right)\sum_{i=1}^{N} \tau_{L_i}{}^m \frac{(1 - l_i)}{(1 - l)} \tag{2.13a}$$

2.2.3 Government

The government runs a balanced budget, so the tax revenue determines its expenditure:

$$G = \sum_{i=1}^{N} \tau_{k_i} r K_i + \sum_{i}^{N} \tau_{L_i} \omega K \,(1 - l_i) \tag{2.14}$$

Using equations (2.2), (2.3), (2.4), (2.12) and (2.13) in (2.14), the share g of government expenditures on output is:

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[69] The aggregation of the relative capital (11b) is an implication of the aggregation of relative incomes (11a) and leisure (11c) and the definition of individual's share of (gross) income (14a).

$$g = \frac{G}{YN} = \frac{1}{N}[(1-\alpha)\bar{\tau}_k + \alpha\bar{\tau}_L] \tag{2.14a}$$

2.3 Equilibrium

The share of gross income and of net income of household i, denoted y_i and ${y_i}^a$ respectively, are as follows:

$$y_i = \frac{Y_i}{Y} = \frac{rk_i + (1-l_i)\omega}{r + (1-l)\omega} \tag{2.15a}$$

$${y_i}^a = \frac{Y_i^a}{Y^a} = \frac{(1-\ \tau_{k_i})rk_i + (1-\tau_{L_i})(1-l_i)\omega}{(1-\ \bar{\tau}_k)r + (1-\bar{\tau}_L)(1-l)\omega} \tag{2.15b}$$

Using the definition of factor returns ω and r in (2.15a) yields:

$$y_i = (1-\alpha)k_i + \alpha\,\frac{(1-l_i)}{(1-l)} \tag{2.15a'}$$

The combination of equations (2.8a) and (2.8b) shows the linear relation between consumption (C_i) and effective leisure (Kl_i), so the expansion path of the economy is a straight line through the origin:

$$C_i = (1-{\tau_{L_i}}^m)\frac{\omega}{\eta}Kl_i \tag{2.16}$$

Using (2.16) the household capital accumulation constraint (2.7) is:

$$\dot{K}_i = (1-\ \tau_{k_i})rK_i + (1-\tau_{L_i})(1-l_i)\omega K - (1-{\tau_{L_i}}^m)\frac{\omega}{\eta}Kl_i - \delta K_i \tag{2.17}$$

Aggregation of (2.17) across households and use of the definition of $\bar{\tau}_k$ given in (2.12) yields: [70]

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[70] Non-linear state transition equations such as (18) do not allow a recursive analysis of the distributional dynamics and the growth. This is because the individual tax rates depend upon both the individual's capital stock and the aggregates, and the equilibrium aggregates and their distribution among households become jointly determined. This is not the case when the tax rates do not vary across individuals, as show in Caselli and Ventura (2000). Aggregation across agents is then straightforward, leading to a macroeconomic equilibrium that is independent of the distribution across agents, and the dynamics can be studied recursively. In the model described here, however, only if one restricts the scope to just two classes of agents ("rich" and "poor") does the formal analysis become tractable, as described in the Koyuncu and Turnovsky (2016). To get a more precise sense of the economy-wide distributional effects of fiscal policy, extending the analysis to a disaggregation based on income quintiles, it is necessary to proceed numerically as detailed in Section 3.

$$\dot{K} = (1 - \bar{\tau}_k)rK_i + (1 - \bar{\tau}_L)(1 - l)\omega K - (1 - {\bar{\tau}_L}^{m})\frac{\omega}{\eta}Kl - \delta K \tag{2.18}$$

Combining equations (2.3), (2.4), (2.17) and (2.18) produces the dynamic equilibrium differential equation that describes the path of $k_i = K_i/K$:

$$\begin{aligned}\dot{k}_i = &\left\{\left(1 - \tau_{k_i}(k_i)\right)r(l)k_i + \left(1 - \tau_{L_i}\right)(1 - l_i)\omega(l) - (1 - {\tau_{L_i}}^{m})\tfrac{l_i}{\eta}\omega(l)\right\} - \\ &-k_i\left\{(1 - \bar{\tau}_k)r(l) + (1 - \bar{\tau}_L)(1 - l)\omega(l) - (1 - {\bar{\tau}_L}^{m})\tfrac{l}{\eta}\omega(l)\right\}\end{aligned} \tag{2.19}$$

The time derivative of (2.15a') yields the dynamic constraint that constrains macroeconomic equilibrium:

$$\dot{y}_i = (1 - \alpha)\dot{k}_i - \alpha\left(\frac{1}{1 - l}\right)\dot{l}_i + \alpha\,\frac{(1 - l_i)}{(1 - l)^2}\dot{l} \tag{2.20}$$

Further, taking the logs and the derivative with respect to time of (2.16) yields the relation between the growth rates of consumption and effective leisure:

$$\frac{\dot{C}_i}{C_i} - \left(\frac{\dot{l}_i}{l_i} + \frac{\dot{K}}{K}\right) = \frac{\omega_l\dot{l}}{\omega} - \phi_L\left(\frac{\dot{\overline{1 - l_i}}}{1 - l}\right)\left(\frac{1 - l}{1 - l_i}\right) \tag{2.21}$$

where $\omega_l = \partial\omega/\partial l.$

Recalling that the numerical analysis in this chapter examines the dynamic responses of applying a flat constant tax rate on labor income ($\phi_L = 0$), which implies that $\tau_{L_i} = {\tau_{L_i}}^{m} = \bar{\tau}_L = {\bar{\tau}_L}^{m}$, equation (2.21) in that case simplifies to:

$$\frac{\dot{C}_i}{C_i} - \left(\frac{\dot{l}_i}{l_i} + \frac{\dot{K}}{K}\right) = \frac{\omega_l\dot{l}}{\omega} \tag{2.21'}$$

Taking logs and the derivative with respect to time of (2.8a) and combining the resulting equation with (2.8c) it yields:

$$(\gamma_i - 1)\frac{\dot{C}_i}{C_i} + \eta\gamma_i\frac{\dot{l}_i}{l_i} = \beta + \delta - (1 - {\tau_{k_i}}^{m})r \tag{2.22}$$

Using this equation to substitute for $\dot{C}_i/C_i$ in equation (2.21’) yields the differential equation for the transitional dynamics of leisure:

$$\begin{aligned}&\left[(1 - \bar{\tau}_k)r + (1 - \bar{\tau}_L)(1 - l)\omega - (1 - {\bar{\tau}_L}^{m})\frac{l}{\eta}\omega - \delta\right] + \left[\frac{\beta + \delta - (1 - {\tau_{k_i}}^{m})r}{(1 - \gamma_i)}\right] = \\ &-\left[\frac{1 - \gamma_i(1 - \eta)}{(1 - \gamma_i)}\right]\frac{\dot{l}_i}{l_i} - \frac{\omega_l\dot{l}}{\omega}\end{aligned} \tag{2.23}$$

Finally, individual household and aggregate growth rates of capital, $\psi_i(t) = \dot{K}_i/K_i$ and $\psi(t) = \dot{K}/K$, respectively are derived from (2.17) and (2.18):

$$\psi_i(t) =$$

$$\frac{A(1-l)^{\alpha-1}}{k_i}\left\{(1-\alpha)\left(1-\tau_{k_i}\right)k_i(1-l)+\alpha\left(1-\tau_{L_i}\right)(1-l_i)-\alpha\left(1-{\tau_{L_i}}^{m}\right)\frac{l_i}{\eta}\right\} \quad (2.24)$$

$$\psi(t) =$$

$$A(1-l)^{\alpha-1}\left\{(1-\alpha)(1-\bar{\tau}_k)(1-l)+\alpha(1-\bar{\tau}_L)(1-l)-\alpha(1-{\bar{\tau}_L}^{m})\frac{l}{\eta}\right\} \qquad (2.25)$$

In the long-run $\psi_i(t)$ and $\psi(t)$ will converge to a common steady-state rate $\tilde{\psi}$, which can be related to the growth rate of output $\psi_y(t) = \acute{Y}/Y$ by differentiating the log of equation (2.1) with respect to time:

$$\psi_y(t) = \psi(t) - \alpha\,\dot{l}(t)/\left(1-l(t)\right) \qquad (2.26)$$

In a steady state (SS) the values of all stationary variables are constant $\dot{k}_i = \dot{y}_i = \dot{l}_i = \dot{l} = 0$, and applying this condition to equation (2.23) yields equation (2.27a) for the steady-state growth rate of the economy, where the rates of return on capital and labor are represented by $r(\tilde{l})$ and $w(\tilde{l})$ respectively, and the tildes denote steady-state values.

$$\tilde{\psi} = \left[(1-\bar{\tau}_k)r(\tilde{l})+(1-\bar{\tau}_L)(1-\tilde{l})\omega(\tilde{l})-(1-{\bar{\tau}_L}^{m})\frac{\tilde{l}}{\eta}\omega(\tilde{l})-\delta\right]$$

$$= \left[\frac{\left(1-{\tau_{k_i}}^{m}(\tilde{k}_i)\right)r(\tilde{l})-\beta-\delta}{(1-\gamma_i)}\right] \qquad i = 1,\dots,N \quad (2.27a)$$

We can now show that that progressive tax structure can lead to a unique non-degenerate distribution in which more affluent households having a higher EIS end up owning a larger fraction of the wealth. From the equation above, consider now individuals from two households $i = 1$ and 2:

$$\tilde{\psi} = \frac{\left(1-{\tau_{k_1}}^{m}(\tilde{k}_1)\right)r(\tilde{l})-\beta-\delta}{(1-\gamma_1)} = \frac{\left(1-{\tau_{k_2}}^{m}(\tilde{k}_2)\right)r(\tilde{l})-\beta-\delta}{(1-\gamma_2)} \qquad (2.27a')$$

Rearranging the equation above, produces an expression that allows the comparison of the effects of the EIS on the relative capital of the two households:

$$\frac{(1-\gamma_1)}{(1-\gamma_2)} = \frac{\left((1-\phi_k)\,\zeta_k\,{\tilde{k}_1}^{-\phi_k}\right)r(\tilde{l})-\beta-\delta}{\left((1-\phi_k)\,\zeta_k\,{\tilde{k}_2}^{-\phi_k}\right)r(\tilde{l})-\beta-\delta}$$

Suppose that the tax rate on capital is progressive $\phi_k > 0$, and that the individual from group 1 has a higher EIS *vis-à-vis* the individual from group 2, i.e. $1/(1-\gamma_1) > 1/(1-\gamma_2)$ so,

$$\frac{(1-\gamma_1)}{(1-\gamma_2)} < 1 \Rightarrow \gamma_1 > \gamma_2 \Rightarrow \left(\tilde{k}_1{}^{-\phi_k}\right) < \left(\tilde{k}_2{}^{-\phi_k}\right) \Rightarrow \tilde{k}_1 > \tilde{k}_2$$

Note also that if all households share a common EIS, the steady state distributions of wealth and income degenerate to zero. Although we are considering a different source of heterogeneity, this result is analogous to the result due to Becker (1980), that with flat (or zero) taxes the most patient individual will accumulate capital at the fastest rate and end up owning all the capital here. However, the heterogeneous EIS coupled with a progressive tax structure avoids the degeneracy.

The following two equations, jointly with the requirement that aggregate labor and capital markets clear, characterize the steady state (equations 27a-d):

$$\left\{\left(1-\tau_{k_i}(\tilde{k}_i)\right)r(\tilde{l})\tilde{k}_i + \left(1-\tau_{L_i}(\tilde{l}_i)\right)(1-\tilde{l}_i)\omega(\tilde{l}) - (1-\tau_{L_i}{}^{m}(\tilde{l}_i))\frac{\tilde{l}_i}{\eta}\omega(\tilde{l})\right\} =$$

$$\tilde{k}_i\left\{(1-\bar{\tau}_k)r(\tilde{l}) + (1-\bar{\tau}_L)(1-\tilde{l})\omega(\tilde{l}) - (1-\bar{\tau}_L{}^{m})\frac{\tilde{l}}{\eta}\omega(\tilde{l})\right\} \quad i = 1,\dots,N-1 \text{(2.27b)}$$

$$\tilde{y}_i = (1-\alpha)\tilde{k}_i + \alpha\frac{(1-\tilde{l}_i)}{(1-\tilde{l})} \qquad i = 1,\dots,N-1 \text{ (2.27c)}$$

$$\frac{1}{N}\sum_{i=1}^{N}\tilde{y}_i = 1 \qquad \frac{1}{N}\sum_{i=1}^{N}\tilde{l}_i = \tilde{l} \qquad \frac{1}{N}\sum_{i=1}^{N}\tilde{k}_i = 1 \qquad \text{(2.27d)}$$

The equilibrium condition in (2.27b) for each income class is obtained from equation (2.19), and shows that the pre-reform SS capital holdings of each income class $(\tilde{k}_i)$ depends on its SS leisure choice $(\tilde{l}_i)$, on the tax rates (τ_{k_i} *and* τ_{L_i}) and the marginal tax on labor income ($\tau_{L_i}{}^{m}$), as well as on the averages of these variables over all income classes, $\tilde{l}$, $\bar{\tau}_k$, $\bar{\tau}_L$.[71]

This next section resorts to numerical simulations to explore the economy-wide impact of tax policy on distribution, due to the difficulty of characterizing analytically in

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[71] As discussed by García-Peñalosa and Turnovsky (2008), wealthier individuals have a relatively lower marginal utility of wealth, and this affects negatively their labor supply. Holtz-Eakin, Joulfaian, and Rosen (1993), Cheng and French (2000) and Coronado and Perozek (2003), for example, provide empirical evidence on how wealth impacts negatively the hours devoted to work.

a general manner the marginal effects of changes in the tax structure. The dynamic responses of the economy to the change in the tax schedule is given by the dynamic system consisting of the $N-1$ accumulation equations (2.19), $N-1$ relative (gross) income equations of (2.20), N equations (2.23), and the aggregations defined in (2.11).

2.4 Calibration for a representative OECD country

The calibration of the baseline parameters and of the initial values of the endogenous variables for the model are summarized in Table 2.1.

The scale parameter of the production function, A = 0.435, is calculated using equation (2.25) to produce an equilibrium growth rate of 2.02% per year, similar to that of high-income countries.[72] The labor output elasticity $\alpha = 0.28$ is an average between the value adopted by K&T and the one adopted by Barro et al. (1995), and is similar to the empirical estimates of Mankiw et al. (1992).[73] This value is around half of the average labor share in production, but this discrepancy can rationalized recalling that L in the model refers to "raw labor".[74] Bearing in mind the broad concept of capital in the model, the depreciation rates for both physical and knowledge capital for the US economy provided by Nadiri and Prucha (1996) are used, $\delta = 0.10$ as in Chen (2020).[75]

The rate of time preference (β) is set to 0.0396, as Atolia et al. (2021), which is well within the range assumed by both Li and Sarte (2004) and K&T. The elasticity of leisure in the utility function (η), which affects how households allocate their time between leisure and work, is set to 0.85. This yields an overall allocation of time to raw

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[72] According to the World Bank data, the average annual percentage growth rate of GDP at market prices of high-income economies was 1.98 from 2000 to 2019.

[73] Mankiw et al. (1992) estimate a Cobb-Douglas production function in which output depends upon labor, human capital, and physical capital, and obtain approximately equal exponents on all three. Barro et al. (1995) assume elasticity of 0.3 for physical capital and 0.5 for human capital.

[74] The labor share in the USA in 2016 was about 58%. Capital, which we interpret broadly as being an amalgam of physical capital and human capital, incorporates the return to labor attributed to "skills".

[75] In general, macrodynamic models such as this are robust with respect to values of δ, consistently set in the range between 0.05 and 0.10, their primary impact being on the rate of convergence.

labor of around 37%, which is consistent with the empirical estimates and observed behavior.[76]

Table 2.1 – Parameters Values for a typical OECD country

Technology parameters	
Scale Parameter (A)	0.435
Elasticity of labor in production (α)	0.28
Capital Depreciation Rate (δ)	0.100
Preference parameters	
Elasticity of leisure (η)	0.85
Rate of Time Preference (β)	0.0396
Individual Elasticity of Intertemporal Substitution $(1/(1-\gamma_i))$	
First quintile: Q1	0.300
Second quintile: Q2	0340
Third quintile: Q3	0.445
Fourth quintile: Q4	0.540
Highest quintile: Q5	0.800
Policy parameters and taxes	
Degree of progressivity of tax rate on labor income (ϕ_L)	0.0634
Degree of progressivity of tax rate on capital income (ϕ_K)	0.0634
Level of tax on labor income (ζ_L) and on capital income (ζ_K)	0.7973

The difference of the EIS among income classes is of crucial importance in determining their heterogeneous behavior of households in the model simulations, and its calibration relies in several studies in the literature. Havranek et al. (2015) estimate values that vary substantially between countries and datasets, but typically are between 0 and 1, with a mean of around 0.5, and few estimates either exceed, or are close to unity, as also indicated by Attanasio and Weber (1993), Ben-Gad (2012), and Gruber (2013). The largest values usually correspond to rich households, as pointed out by Havranek et al. (2015), Blundell et al. (1994), and Attanasio and Browning (1995). Vissing-Jørgensen (2002) find larger EIS for stockholders than for non-stockholders. On the other hand, poor households have a smaller EIS, as implied by Bayoumi (1993) and Wirjanto (1995) that

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[76] In 2019, the average hours worked per week in the USA by persons who usually work full time was 42.5, according to U.S. Bureau of Labor Statistics data, available at https://www.bls.gov/cps/cpsaat22.pdf. Assuming that they work on average 50 weeks per year and their time endowment available for allocation is 2/3 per day implies an overall allocation of time to labor of around 36.4%.

find that is the case for liquidity-constrained households. Atkeson and Ogaki (1996) find that the EIS differs between rich and poor households in India, being smaller for the latter, because they spend a larger share of their budget in the consumption of subsistence and necessary goods, which is harder to reallocate over time.

To calibrate the EIS in the model of this chapter, which has five household types that correspond to quintiles of the income distribution, its value for each class is set according to the evidence in the previous paragraph, as follows. For the highest income quintile, EIS = 0.8, which implies $\gamma_5 = -0.25$, which is the value estimated by Atkeson and Ogaki (1996) for the richest group in their dataset. For the lowest income class, EIS=0.3, i.e. $\gamma_1 = -2.33$ is chosen, because it is representative of the lowest values in the indicated range. For the other quintiles, they are set to intermediary values, declining from the largest to smallest values above. This schedule implies an economy-wide average EIS of 0.485, approximately equal to 0.5, which is the value adopted by most aggregate macroeconomic simulation models as, for example, Lucas (1990), Baier and Glomm (2001), Kitao (2010), Angyridis (2015) and K&T.

In the benchmark simulation, the parameters of the fiscal function are set to the average values estimated by Chen and Guo (2013) for the period 1987-2005: $\zeta_L = \zeta_k = 0.797$ and $\phi_L = \phi_k = 0.0634$. These yield an economy-wide average tax rates on labor and capital income of respectively $\bar{\tau}_L = 20.64\%$ and $\bar{\tau}_k = 23.01\%$ which are consistent with the observed average federal taxes reported by CBO.[77] The economy-wide average marginal rates are $\bar{\tau}_L{}^m = 25.67\%$ and $\bar{\tau}_k{}^m = 27.89\%$ which are consistent with the historical average marginal rates used in NBER's TAXSIM model, [78] and their difference is very similar to that found in Chen (2020).

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[77] Available at: https://www.cbo.gov/publication/57061. The rates on labor income are also somewhat similar to the employee net average tax rate reported to US (22.4%) and OECD (24.8%) countries in 2020, according to Taxing Wages 2021 Report available at: https://www.oecd.org/unitedstates/taxing-wages-united-states.pdf .

[78] Available at: http://users.nber.org/~taxsim/marginal-tax-rates/

2.5 Benchmark equilibrium and policy simulations

Table 2.2 shows the main variables of the model in the initial SS benchmark equilibrium. A household in highest income quintile works very little (1/3 of average), has about three times the average capital holdings ($k_5 = 3.19$) and its earned income is about 2.4 times that of the average household. On the other hand, a household in lowest income quintile works about 26% more than the average and holds only 1.8% of the total wealth, and its income is about 42% of the average income.

The GINI coefficient, which is the conventional empirical measure of overall income inequality, is approximately equal to the following expression when there are N income classes:

$$GINI = \frac{N+1}{N} - \frac{2\sum_{i=1}^{N}\left(N+1-i\right)y_i}{N\sum_{i=1}^{N}y_i} \tag{2.28}$$

Hence, in the initial steady state value of the GINI coefficient of income is equal to 35.8, which compares to the historical average of the GINI income coefficient in high-income economies of 38.4.[79]

The distribution of capital and the differences in labor supply across households lead to variations in the tax rates across the quintiles, as indicated by tax function in equations (2.6a) and (2.6b). The tax on capital income ranges from 25.9% for Q5 to 7.1% for Q1 and the tax on labor income ranges from 14.5% for Q5 to about 20% for Q1-Q4. This yields an overall tax revenue in the benchmark economy is 22.35% of total output.

The following subsections simulate numerically the growth and distributional effects of two fiscal reforms aimed at improving the income distribution, which take into consideration that the households in the bottom of the distribution receive most of their income from labor, while most of the capital income accrues to those at the top. While keeping the fiscal scheme progressive, it is possible to improve the distribution by reducing the progressivity of the tax on labor and maintaining, or increasing, the progressivity of the tax on capital income. These alternatives are considered in Scenario

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[79] According to the World Bank data, available at: <https://data.worldbank.org/indicator/SI.POV.GINI?most_recent_value_desc=true>

A that makes $\phi_L = 0$, and Scenario B that couples that change with an increase of 25% in ϕ_K.

Table 2.2 – Initial Steady-State Equilibrium [80]

	Growth rate ($\tilde{\psi}$)	Aggregate Labor share	$\bar{\tau}_k$	$\bar{\tau}_k{}^m$	$\bar{\tau}_L$	$\bar{\tau}_L{}^m$
Aggregate Variables	2.02%	0.373	23.01%	27.89%	20.64%	25.67%

	Income Shares ($\tilde{y}_i$)	Capital Shares ($\tilde{k}_i$)	Labor Allocation ($\tilde{L}_i$)	τ_{k_i}	$\tau_{k_i}{}^m$	τ_{L_i}	$\tau_{L_i}{}^m$
Q1	0.418 (8.36%)	0.089 (1.78%)	0.4713	7.06%	12.95%	21.45%	26.43%
Q2	0.484 (9.69%)	0.164 (3.28%)	0.4872	10.59%	16.26%	21.61%	26.58%
Q3	0.693 (13.85%)	0.516 (10.32%)	0.4274	16.85%	22.12%	20.96%	25.97%
Q4	1.016 (20.31%)	1.042 (20.85%)	0.3524	20.48%	25.52%	19.99%	25.06%
Q5	2.389 (47.79%)	3.189 (63.77%)	0.1247	25.92%	30.62%	14.54%	19.96%

2.5.1 Scenario A - Flat taxes on labor income

This scenario aims to capture the effects eliminating the progressivity of the tax on labor income, by setting the progressivity parameter of the tax rate function on labor income (ϕ_L) to zero while maintaining the level parameter (ζ_L) at its original value in equation (2.6a). The parameters of the tax rate function on capital income are unaltered in equation (2.6b). The tax rate on labor income becomes equal to 20.3%, independent of the agent's relative labor income, and the long-run economy wide tax burden remains virtually constant at the pre-reform level. On impact, this policy increases the tax rate on labor income of Q5 by 5.73 p.p., while for Q2 and Q1 it decreases by 1.34 p.p. and 1.18 p.p., respectively. Recalling the specification of the tax function (eq. 2.6a), the direction

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[80] The *relative* capital and income in these numerical simulations ($\tilde{k}_i$ and $\tilde{y}_i$) are equal to $\frac{K_i}{K}$ and $\frac{Y_i}{Y}$, respectively, and the shares of total capital and income displayed in parenthesis are these ratios divided by N (in our case, N=5) so that $\left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(\frac{Y_i}{Y}\right) = 1$ and $\left(\frac{1}{N}\right)\sum_{i=1}^{N}\left(\frac{K_i}{K}\right) = 1$, as indicated in equation (2.11a). The presentation of the simulations below preserves this manner of presenting the results of the model.

of these changes is expected because the elimination the progressivity benefits the quintiles that work more hours relatively.[81] Table 2.3 shows the changes on impact and in the SS level of all variables, displayed as proportional deviations (times 100) from the benchmark in all cases, except for the annual growth rates of capital ψ_i and the tax rate on capital income (τ_{k_i}), which are shown in percentage points. Figure 2.1 shows the trajectories of the main variables for each quintile, which indicate a smooth transition, and Graph 2.1 displays the transitional dynamics of the rate of capital accumulation.

The first column of Table 2.3 shows the short run "on impact" of these fiscal changes. There is an initial upward jump in aggregate labor supply, as expected from a policy that reduces the progressivity on labor income. All quintiles increase immediately their work effort except for the wealthier households, for which the tax rate on labor income increases by 5.73 p.p. (see last part of Table 2.3).[82] This overall increase in aggregate employment reduces the wage and increases the rate of return on capital, inducing the long run increase in the rate of capital accumulation of all income quintiles. The change on impact in rates of capital accumulation of the quintiles (ψ_i) vary widely across the quintiles, as shown in the second column of the first part of the table and in Graph 2.1.

While Q3, Q4 and Q5 boost the rate of capital accumulation, Q1 and Q2 reduce their growth rate of capital, but the aggregate rate (ψ) nevertheless increases by 0.12 p.p.. The latter effect occurs because the reduction in the marginal tax rate on labor of the poorer quintiles leads to an increase in consumption which dominates the increase in after-tax income, and therefore to a decrease of their rates of saving and capital accumulation. For Q5, however, the marginal tax rate on labor increases and leads to a reduction in consumption, and an increase in savings and capital accumulation. The rates of capital accumulation of Q3 and Q4 increase mildly on impact, but because this increase is smaller than the average increase, their relative share of the capital stock decreases

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[81] The pre-reform tax rate on labor income was a function of the agent's labor supply. Consequently, individuals who worked relatively more, and thereby earned more income from labor than the average, were subject to a relatively higher tax rate. Therefore, all income groups that work more hours than the average (Q1-Q3) are benefited by the elimination of progressivity on labor income taxation.

[82] Recalling the empirical evidence regarding the positive relationship between an agent's relative wealth and his allocation of time to leisure (Turnovsky and García-Peñalosa, 2008), wealthier households tend to work fewer hours than average. Accordingly, the results reported in this section show that the top income quintile is hurt on impact by the policy that flattens the tax rate on "raw" labor income, as the immediate effect is to increase the tax rate for those who work less hours than the aggregate labor supply.

during the transition. Nevertheless, the long run rate of capital accumulation of all quintiles (ψ_i) increase by 0.136 p.p., as shown in Table 2.3.

The first and second lines of Figure 2.1 show the transitional dynamics of the relative share of capital stock and of income of each quintile, which are quite similar. This is due to the approximately linear relation between them within each quintile, which inferred from equation (2.15a') by noticing that the variations of the ratio $(1-l_i)/(1-l)$ between the initial and final SS are small for most quintiles (see below). Broadly speaking, the ratio of the vertical scales of the paths of these two variables is $(1-\alpha)=0.72$. They decline steeply after the shock and then asymptotically approach the final SS for all quintiles except for Q5, where the slope of the path is positive. Table 2.3 shows the changes in the share of total capital of Q5 and Q1, that in the initial SS are 63.8% and 1.8%, and in the long run after the policy change increases to 65.7%, and the declines to 1.5%, respectively. This positive result for Q5 is an effect of the extra incentive to accumulate capital triggered by the fiscal reform and those households end up owning a larger share of post-reform capital. The shares of Q3 and Q4 in total capital display the largest reduction among the quintiles, which explains the evolution of their income share displayed in the second line of Figure 2.1.

Graph 2.1 – Transition Dynamics of the Rate of Capital Accumulation in Scenario A

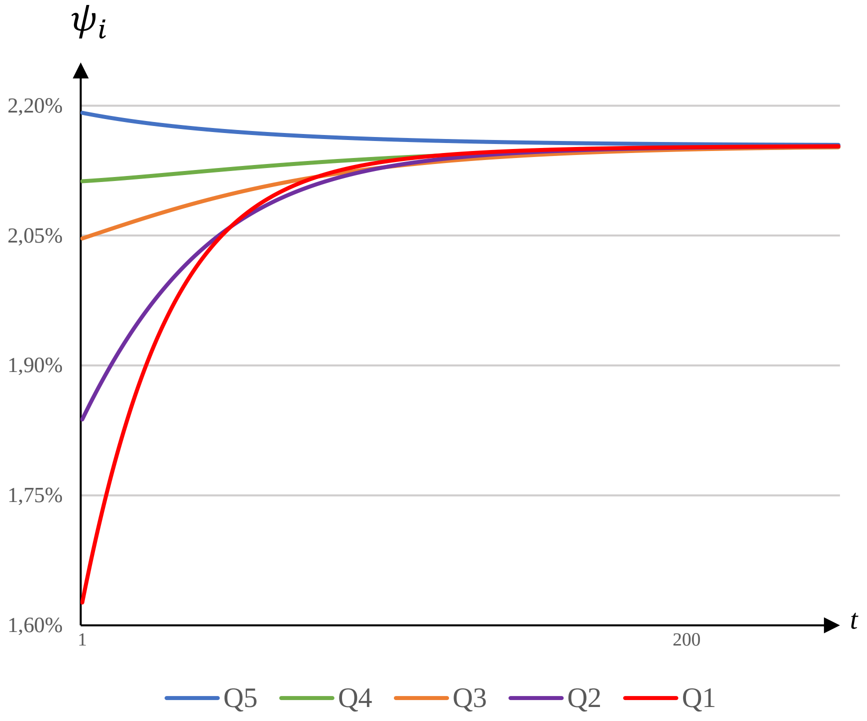


Table 2.3 – Impact and long-run effect of Scenario A

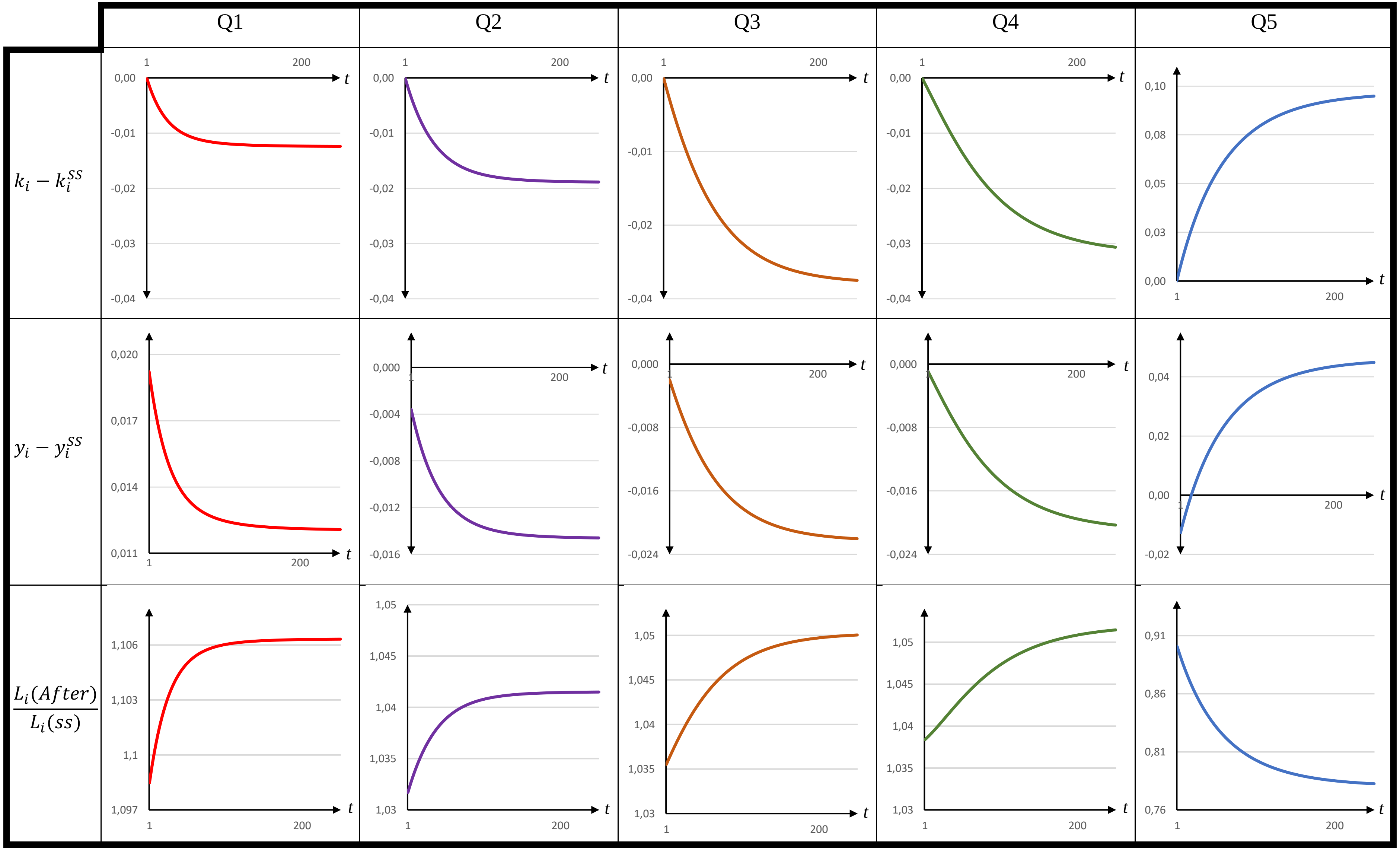
	$Impact$	$Long - Run$
ψ (*)	0.121	0.136
ψ_1 (*)	-0.392	0.136
ψ_2 (*)	-0.180	0.136
ψ_3 (*)	0.029	0.136
ψ_4 (*)	0.095	0.136
ψ_5 (*)	0.174	0.136
ΔL_1	0.046	0.050
ΔL_2	0.015	0.020
ΔL_3	0.015	0.021
ΔL_4	0.014	0.018
ΔL_5	-0.012	-0.027
Δy_1	0.019	0.012
Δy_2	-0.004	-0.015
Δy_3	-0.002	-0.022
Δy_4	-0.001	-0.021
Δy_5	-0.013	0.046
$\Delta y_1{}^a$	0.024	0.017
$\Delta y_2{}^a$	0.002	-0.009
$\Delta y_3{}^a$	0.000	-0.019
$\Delta y_4{}^a$	-0.003	-0.021
$\Delta y_5{}^a$	-0.023	0.032
Δk_1	0	-0.012
Δk_2	0	-0.019
Δk_3	0	-0.033
Δk_4	0	-0.032
Δk_5	0	0.097
$\Delta \tau_{k1}$(*)	0	-0.889
$\Delta \tau_{k2}$(*)	0	-0.696
$\Delta \tau_{k3}$(*)	0	-0.355
$\Delta \tau_{k4}$(*)	0	-0.157
$\Delta \tau_{k5}$(*)	0	0.140

Notes: (*) deviations in percentage points.

(+) for all variables the index $i = 1, \dots, 5$ represents the quintiles of income distribution.

(a) the variables $\Delta y_i{}^a$ are the proportional change in the available income of the i-th quintile.

Figure 2.1 – Dynamic Effects of Scenario A



The long-run effect on the relative incomes $(y_i - y_{i(SS)})$, in the second line of Figure 2.1, are positive only for Q5 and Q1, although the transition paths are quite distinct between these quintiles.[83] Since the highest quintile accumulates capital at a faster rate after the fiscal reform, it becomes relatively wealthier throughout the transition and, hence, increases its relative income. For Q1, instead, the policy results in an immediate increase in y_1 $(\Delta y_1 = 0.019)$ which is not sustained during the transitional path and in the new steady-state $\Delta y_1 = 0.012$. Due to the jump in labor allocation, there are powerful positive effects in the short-run that are attenuated during the transition as the reduction of their capital share negatively affects their total income.

At first glance, it may seem somewhat surprising that Q5 increases its long-run relative income share, since the policy raises the tax rate on the labor income of the richest while reducing that of the poorest income classes. In fact, immediately after the tax reform the effects are positive from the distributional perspective, reducing the income inequality as reported in the middle column of Table 2.3. However, since the fiscal reform reduces the after-tax wage of the top quintile but also increases the return to capital, the consequence is an increase in their savings. For the bottom quintiles, in contrast, the consumption effect of the tax cut is powerful, resulting in a decline in the rate of asset accumulation. Hence, the immediate effects on both income and capital distributions are reversed during the transition, and in the long-run the inequality problem is deepened.

The third line of Figure 2.1 shows that only the households in Q5 work less and enjoy more leisure in the post-reform equilibrium, as could be expected from the elimination of the progressivity of the tax on labor income. The households in all other quintiles increase their work effort and, on impact, the increase for Q1 is three times larger than that of Q2-Q4. Through time, this differentiated effect across the quintiles continues as a trend, and in the long run, the average economy-wide level of employment increases by 1.6 p.p.[84]

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[83] As indicated before, the dynamics of the deviation of the level of income from those in the initial steady state $(y_i - y_i^{SS})$ follow that for the deviations of capital $(k_i - k_i^{SS})$ and will not be commented further.

[84] Indeed, there is ample empirical evidence that an increase in the progressivity of the tax structure has an adverse effect on labor supply, a fact that confirms the relevance of making the labor supply endogenous. For example, Hausman (1981), Blomquist (1983), Blomquist, Eklöf and Newey (2001) and Guvenen, Kuruscu, and Ozkan (2014) find that higher progressivity reduces hours of work in their studies. Koyuncu (2011) documents how the reduction in progressivity in the US between the periods 1971-74 and 1986-89 and the increase in progressivity in Germany over the same time was associated with an increase in hours worked in the US and a decline in hours worked in Germany.

Summarizing the effects of the removal of the progressivity of labor income taxation simulated in this Scenario, we find a modest long-run tradeoff between growth and inequality. The aggregate growth rate increases by 0.136 p.p., but there is a mild increase in wealth and income inequality, and the GINI coefficient for income increases slightly from 35.8 to 36.3. The effects of the policy on the overall tax revenue are surprisingly small, as it declines only 0.1 p.p. on impact, and increases 0.03 p.p. in the long run, due to its positive effect on income. This, however, comes at the expense of an increase of work hours and a decrease in leisure of all quintiles, except the highest income.

2.5.2 Scenario B - Flat taxes on labor income and more progressive capital taxation

The previous section reveals the inability to reduce inequality of a tax policy change that alters the taxation of labor income without altering that of capital income. In the light of that outcome, this section examines the dynamic effects of a policy designed also to redistribute capital income towards the poorest quintiles, by combining the elimination of labor income tax progressivity with an increase in the progressivity of capital income taxation. The increase of ϕ_k in this Scenario B is set to 25%, so $\phi_k = 0.07925$ and $\phi_L = 0$. This shifts the tax burden further to the relatively wealthier households, and increases the redistributive effect of the policy, which was rather small in Scenario A. Table 2.4 summarizes the changes on impact and the long-run effect of this policy, and Figure 2.2 shows the transitional dynamics of the main variables, all relative to the initial equilibrium. Graph 2.2 indicates the progressive reversal in the long run of the impact effects of the fiscal reform.

The comparison of results reported in Table 2.4 with those of Scenario A in Table 2.3, indicates the deleterious effects of the increase in the progressivity of capital taxation on the growth rate of income of the highest quintile, as the short run impact on ψ_5 is negative. For Q4 the impact is virtually null, while Q3, Q2 and Q1 accumulate capital at a faster rate, especially the latter, whose growth rate increases by about 3.2 p.p. However, the impact on the capital accumulation itself, and therefore on economic growth, depends on the capital holdings of the respective households, and the decline capital accumulation of the richest quintile $\left(\psi_5 * k_5 = -0.461 * 3.189/5 = -0.294\right)$ is larger than the increase for the poorer quintiles $\left(\sum_{i=1}^{i=4} \psi_i * k_i\right)$. The net effect is an immediate short-run decline in the aggregate (and average) capital which leads to a decline of the growth rate of the economy accumulation ($\psi = -0.133$). These changes are a direct effect of the tax reform, since the steeper progressivity of the capital taxation in this scenario immediately leads to a reduction of 3.63 p.p. in the tax rate of Q1, and to an increase of 1.35 p.p. in the tax rate of Q5, and to smaller changes in the tax rate of the other quintiles. The tax burden of each quintile depends on their respective capital holdings, and the aggregate tax revenue increases by 0.35 p.p. on impact, but the following transition reverses this effect, resulting in a long-term reduction of 0.5 p.p. This effect is markedly different from that in Scenario A, where that change was negligible.

The main driver of the decline of the economy-wide growth rate is the reduction of the relative capital of Q5 (k_5), that is a consequence of the reduction of its rate of capital accumulation (ψ_5). As showed in Graph 2.2, the speed of adjustment is very large in the beginning of the transition, until about $t = 20$, but declines progressively, and the rate of capital accumulation of the several quintiles only converge towards the end of the horizon considered in these simulations ($t = 200$).

Graph 2.2 – Transition Dynamics of the Rate of Capital Accumulation in Scenario B

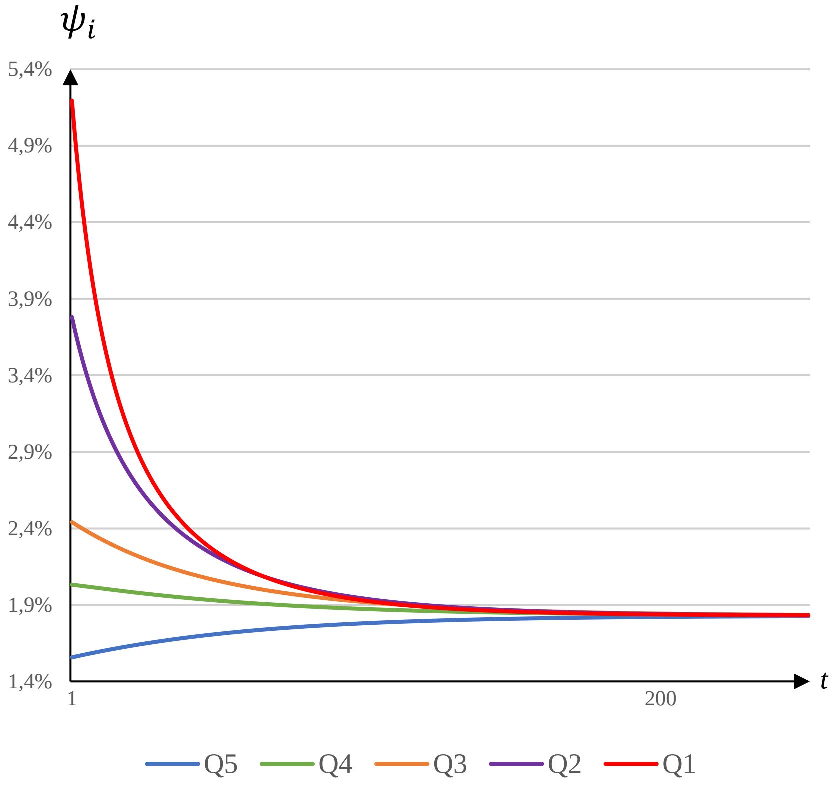

Table 2.4 – Impact and long-run effect of Scenario B

	$Impact$	$Long-Run$
ψ (*)	-0.133	-0.188
ψ_1 (*)	3.178	-0.188
ψ_2 (*)	1.763	-0.188
ψ_3 (*)	0.423	-0.188
ψ_4 (*)	0.014	-0.188
ψ_5 (*)	-0.461	-0.188
ΔL_1	0.052	0.025
ΔL_2	0.021	-0.011
ΔL_3	0.018	-0.015
ΔL_4	0.013	-0.005
ΔL_5	-0.033	0.050
Δy_1	0.025	0.081
Δy_2	0.002	0.078
Δy_3	0.001	0.109
Δy_4	0.000	0.079
Δy_5	-0.028	-0.346
$\Delta {y_1}^a$	0.036	0.093
$\Delta {y_2}^a$	0.014	0.090
$\Delta {y_3}^a$	0.012	0.108
$\Delta {y_4}^a$	0.003	0.064
$\Delta {y_5}^a$	-0.065	-0.355
Δk_1	0	0.098
Δk_2	0	0.131
Δk_3	0	0.176
Δk_4	0	0.123
Δk_5	0	-0.528
$\Delta \tau_{k1}$(*)	-3.631	1.880
$\Delta \tau_{k2}$(*)	-2.597	1.583
$\Delta \tau_{k3}$(*)	-0.877	1.058
$\Delta \tau_{k4}$(*)	0.052	0.753
$\Delta \tau_{k5}$(*)	1.349	0.297

Notes: (*) deviations in percentage points.

(+) for all variables the index $i = 1, \dots, 5$ represents the quintiles of income distribution.

(a) The variables Δy_i^a are the proportional change in the available income of the i-th quintile.

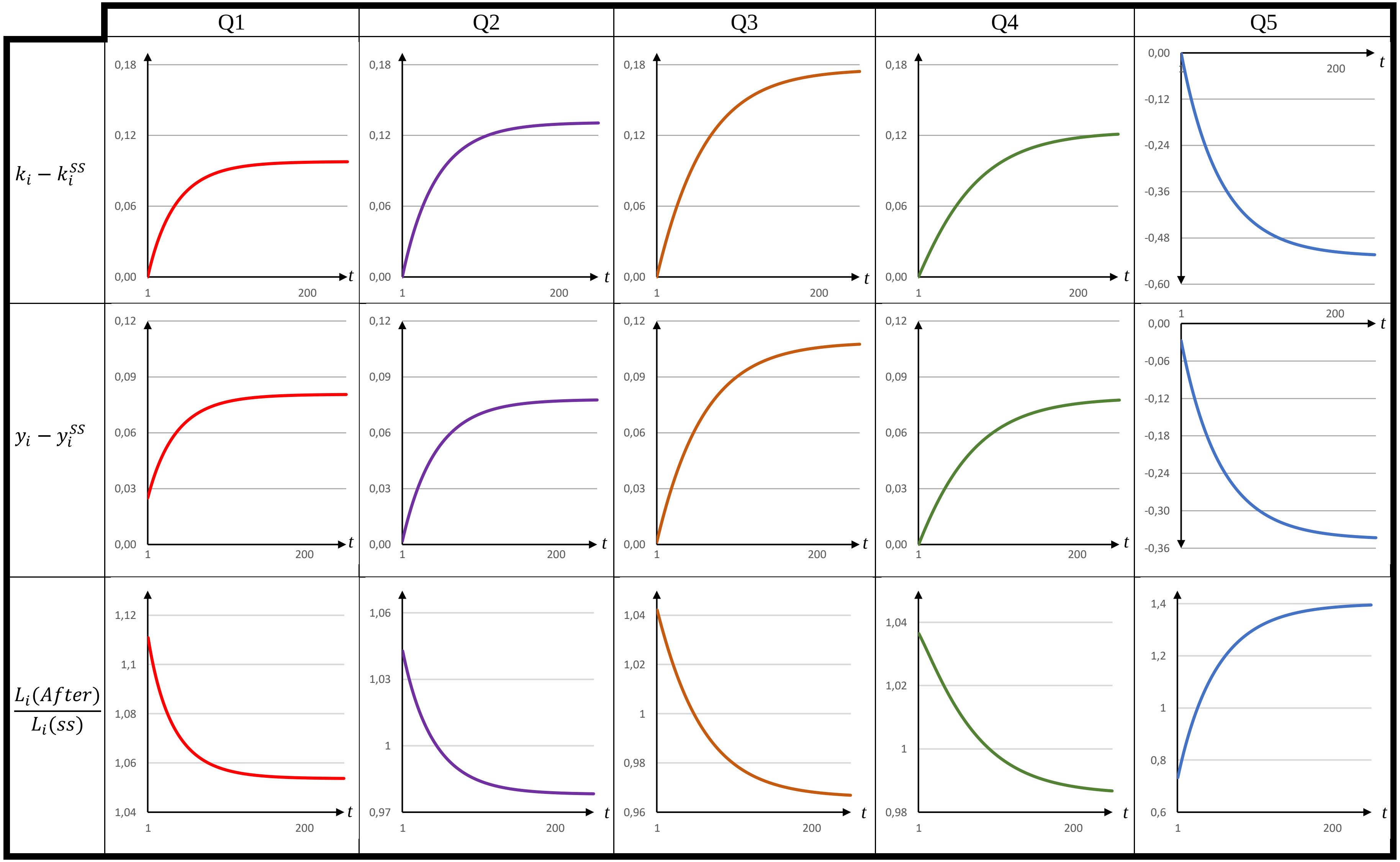

Figure 2.2 – Dynamic Effects of Scenario B

The first and second lines of Figure 2.2 show that quintile most affected by the redistributive effect is Q5, whose share of capital declines by 10.6 p.p., [85] and relative income (y_5) declines from 2.39 to 2.04. All other quintiles display significant positive effects in these indicators and, in particular, the poorest quintile increases its pre-tax income (y_1) on impact, through the jump in its work effort, and in the transition, through the increase of its capital accumulation, which rises its income share from 8.36% to 9.98% in the long run (see also Table 2.4). This effect is in marked contrast with the previous scenario, where relative gain of Q1 decreases during the transition, and the redistributive effect benefits the richest quintile, whose long run relative income and capital shares increase at the expense of the decline in that of Q2-Q4. Overall, Figure 2.2 indicates that the increase in the progressivity of the capital income tax introduced in this scenario makes the distribution of capital and income more equitable in the post-reform equilibrium, as expected, reducing the income and capital GINI index by 6.8 p.p. and 10.1 p.p., respectively. However, recalling that in the post-reform steady state the common growth rate decreases by 0.19 p.p. relative to the pre-reform steady state, this indicates a tradeoff between growth and inequality that now matches the empirical evidence (Blomquist et al. 2001; Koyuncu 2011).

Comparison of the third line of Figures 2.1 and 2.2 shows that the impact effects of the policies in the current and previous scenarios are similar, but that in the transition they are quite different, and in most cases the sign of the slope of the trajectory in scenario B is the inverse of that in the scenario A. While the richest quintile (Q5) was the only one to enjoy more leisure in the post-reform equilibrium in the previous scenario, in the current scenario its work effort increases progressively during the transition. In the current scenario Q2, Q3 and Q4 gradually increase their consumption of goods and leisure in the early stages of the transition path, and supply less labor in the long run. Also in scenario B, the poorest quintile (Q1) exhibits declining work effort during the transition, but this reduction is not sufficient to offset the increase on impact, and in the post reform steady state, these households still work more than in the benchmark equilibrium.

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[85] The formula for these shares is $\frac{1}{N}\frac{K_i}{K}(\times 100)$. The data for relative capital is reported in Table 2.2 and 2.4, and is, for the lowest and highest income quintiles respectively, ${k_1}^{SS} = 0.089$, ${k_1}^{AFTER} = 0.187$, ${k_5}^{SS} = 3.19$, and ${k_5}^{AFTER} = 2.66$.

In summary, the tax policy of scenario B, which supplements the removal of the progressivity of the labor income taxation with the increase of the progressivity of the capital income taxation, avoids the troublesome results of scenario A, and yields an equilibrium that displays the expected negative effects on growth of policies designed to reduce inequality.

2.6 Concluding Remarks

This chapter examined the effects of a fiscal reform that eliminates the progressivity of the tax on labor income and increases the progressivity of the tax on capital income using a general equilibrium dynamic model with heterogeneous households distinguished by their EIS.

The simulation of a calibrated version of the model for two scenarios designed to represent alternative policies aimed to increase the tax benefits in favor of the poorer quintiles allowed the quantification of the effect the progressivity of the tax structure has in the growth-inequality tradeoff. This quantitative assessment is more precise than others found in the literature because the model here uses a disaggregation of the income distribution by quintiles, and the representation of the tax structure accounts for the source of income. These extensions allow a richer analysis of the dynamic adjustment of the economy and, especially, permits a more detailed evaluation of the burden and benefit of the policies across the quintiles.

The main insight is that a fiscal reform that eliminates the progressivity of the tax rate on labor income and increases the progressivity of the tax on the capital income by 25% simulated in scenario B has a significant redistributive effect. In the long run the shares of capital and income of the highest quintile decreased by 10.6 p.p. and 6.9 p.p., respectively, while the poorer quintile increased its share of total income from 8.37% to 9.98%. This is in contrast to scenario A that also simulates the elimination of the progressivity of the tax on labor income, but maintains the tax on capital income at its baseline level. In that case, the fiscal policy yields positive effects on growth, but results in a long-run increase in the GINI coefficients for both income and capital. More specifically, the more progressive capital income taxation of scenario B countervails troublesome effects on the income distribution of the policy in scenario A, where the highest quintile is the only one that increases its long run relative capital share, due to the increase of its rate of asset accumulation.

In sum, the results show that the degree of progressivity of the tax rate on capital income plays a crucial role in determining the impact of structural changes on growth and inequality. The dramatic drop in the GINI coefficients in scenario B reveals that increase the progressivity of capital income taxation is effective in tackling inequality, but at the cost of a reduction of the aggregate growth rate of the economy, both the short and long run. The latter is a consequence of the fall of the growth rate of capital accumulation of the top quintile which is not compensated by the increase the growth rates of capital accumulation of the poorer quintiles, an effect that, by the way, highlights that heterogeneity among agents is critical. Therefore, given that this model incorporates only one source, albeit it a key one, an analysis under different assumptions regarding the sources of heterogeneity merits further consideration.

3 DISTRIBUTIONAL DYNAMICS AND GROWTH EFFECTS OF FISCAL POLICY UNDER PROGRESSIVE TAXATION

3.1 Introduction

The study the growth-inequality tradeoff and the design of tax policy for the reduction of income inequality often relies on the construction, calibration and simulation of dynamic general equilibrium (DGE) models that include a government sector. Most of the studies in the literature that use that approach consider flat-rate tax systems [86] but some studies, such as Sarte (1997), and Li and Sarte (2004), have included in their formulation the progressive tax codes found in the actual economies. These papers, and those that followed in this strand of the literature, mostly attribute household heterogeneity to differences in the rate of time preference and assume inelastic labor supply, as discussed in the literature review of the previous chapter. It turns out that both of these assumptions are of crucial importance to determine the dynamic behavior of their models and for the conclusions draws from them. They also generally have another limitation, which is the lack of detail with respect to the dynamics of the transition, since they mostly restrict their analysis to the effects of the policies on the equilibrium balanced growth path of the economy. The model proposed here addresses all of these three limitations, as follows.

As indicated by Bosi and Seegmuller (2010), the elasticity of labor supply plays a key role in determining the effects of changes in the progressivity of the income taxation. Indeed, this feature captures how fiscal policy affects the hours devoted to work, which is relevant in a context where the net labor income varies with the household's total income. Carroll and Young (2009), Angyridis (2015) and Koyuncu and Turnovsky (2016), henceforth K&T, have taken this effect into consideration in their models and shown that it in its presence fiscal policy requires larger changes in the tax rates to achieve the intended results. K&T also discuss the entire adjustment path, as well as the rate of

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[86] See, for example, Stokey and Rebelo (1991), Mendoza, Razin, and Tesar (1994), Domeij and Heathcote (2004), and García-Peñalosa and Turnovsky (2007, 2011).

convergence to the steady state. More recently, following a similar approach, Chen (2020) extends this literature further by assessing the inequality effects of separate progressive tax schemes for labor income and capital income, like the one considered in the previous chapter. The general conclusion of these papers is that more progressivity in taxation reduces work incentives (e.g., Koyuncu, 2011; Chen, 2020) and capital accumulation (e.g., Krueger and Ludwig, 2013; Guvenen, Kuruscu, and Ozkan, 2014), and therefore, economic growth. This finding is in line with the empirical evidence from earlier studies, such as Hausman (1981), Blomquist (1983) and Blomquist, Eklöf and Newey (2001).

The model proposed here shares several of the characteristics of the one in the previous chapter. It assumes complete markets, is tractable, and leads to a non-degenerate distribution of income and wealth. The numeric simulation also considers five household types instead of the two types that K&T use. The stratification of the income distribution by quintiles allows the model to produce a more detailed description of the effects of the policy, both in the steady state and in the dynamic adjustment path, since the high asymmetry and skew of the population density function of income is difficult to capture with only two household types. Further, for taxation studies the number of income classes should, in principle, be consistent with the income brackets of the tax code.

It also specifies the households' heterogeneity in a manner that is qualitatively different from previous studies that rely on the differentiation of their rates of time preference.[87] This alternative treatment avoids a problem of that approach which is that, to yield in the model the observed income distribution, the required variations of that parameter across the income classes are too large and incompatible with the estimates for that parameter found in the empirical literature, as discussed in Carneiro et al. (2022). The characterization of heterogeneity considered here, differences in the elasticity of intertemporal substation (EIS) across income classes, displays a much wider range of variation in the empirical literature, and therefore has a larger potential for better reproducing in the model the observed income distribution.[88]

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[87] Another possible source of heterogeneity is with respect to labor productivity, as in Carroll and Young (2009), which also leads to equilibrium with non-degenerate wealth distributions. Koyuncu (2011) considers both these sources of heterogeneity in his model, and studies patterns of working hours in USA and Germany. The source of heterogeneity considered here, the differences in the IES among cohorts, has larger potential variation for households of different income class than either these formulations.

[88] There are other dimensions of heterogeneity, which may also be important for intertemporal choices. For example, the access to financial markets also contributes to the differences among consumers' willingness to substitute consumption through time, as only those households who hold a given asset have reasons to

The aggregate EIS is a key parameter in the relationship between steady state great ratios and growth, as shown by Attfield and Temple (2010), and its effect on the fiscal and monetary policies and in long-run economic growth and welfare has been extensively studied with growth models (e.g.; King and Rebelo 1990; Rebelo 1992; Easterly et al. 1994). However, different EIS among cohorts has not often been used to indicate heterogeneity of in macroeconomic growth models, with the exceptions to be discussed later in the section on calibration. Further, since the risk aversion coefficient frequently characterizes heterogeneity in stochastic models, and corresponds to the inverse of the EIS in deterministic models, the fact that it varies widely with income is an indication that is satisfactory for the characterizing heterogeneity here.

The model in this chapter modifies the one in the previous chapter mainly with respect to the formulation of the tax function, by taking into account the existence of income transfer policies from the Government to the households, and by refining the calibration of the parameters of the model to reflect the US economy. The first extension, detailed in the next section, leads to a more realistic reproduction in the model of the observed US tax code. The second extension, taking explicit account of public transfers, allows a portion of household income not to depend on effort, and this has relevant qualitative importance in their behavior. These two extensions, together with the third, enhanced calibration, greatly improve the capacity of the model to tackle actual policy issues and quantify the effects of fiscal reforms that are under currently consideration. Indeed, these modifications attempt to refine the assessment of the effects on economic growth and income inequality of the USA Tax Cuts and Jobs Act (TCJA)[89] of 2017 in Carneiro et al. (2022), by refining the modeling of one of its main policy changes, namely, the reduction of the top marginal rate from 39.6 to 37 percent. They, together with other refinements of the estimates of the modifications of the other fiscal parameters that model

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change their consumption growth rate due to variations in its return as observed by Vissing-Jørgensen (2002). His estimates of the IES of agents that do not hold assets are close to zero, and are significantly positive for stockholders and for bondholders. Guvenen (2006) incorporates this feature to an RBC model and considers an economy with two types of households, where the stockholders have higher IES vis-à-vis the non-stockholders, and find that the high-elasticity agents end up owning virtually all the capital stock in the economy, whereas consumption is more evenly distributed the two types of households.

[89] More details about the TCJA 2017 can be accessed at: https://bit.ly/law_115-97 .

it, lead the numerical solution of the model to track more closely in the subsequent years the observed distributional dynamics of that policy.[90]

The organization of the rest of this chapter is as follows. Section 2 presents the specification of the model, while Section 3 discusses the equilibrium. Section 4 discusses the calibration of the tax function and of the other parameters of model. Section 5 discusses the benchmark case, as well as of the simulations of the effect of a tax cut that follows the spirit of the TCJA 2017, showing its effect on inequality and growth in the long-run, and on the dynamic path. In the numerical simulations we also use a version of the model that considers both sources of heterogeneity: differences in the elasticity of intertemporal substitution and in the rate of time preference. Section 6 contains final considerations and conclusions.

3.2 Model Specification

The model used here, like the one in the previous chapter, is an adaptation of the K&T endogenous growth model with progressive taxation of income and elastic labor supply to consider heterogeneous agents distinguished by their EIS rather than their rate of time preference. The calculation of the perfect foresight general equilibrium solution reduces to the solution of a set of deterministic equations where all variables are time-dependent. However, to simplify the notation, this time dependence is not explicit in the model specification. The following paragraphs briefly review its characteristics, for completeness.

The production function is of the type proposed by Romer (1986) to yield a model capable of displaying endogenous growth in a competitive economy where the marginal physical product of factors determine the equilibrium factor prices. There are N households indexed by i, which have an infinite planning horizon, and maximize the present value of utility discounted at the rate of time preference (β), with the same isoelastic utility function defined in the previous chapter (section 2.2.2).

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[90] Of course, the tracking of the model is only approximate, given that it is a highly simplified representation of the actual economy, but it is nevertheless a substantive effort to study the effects of an actual fiscal policy.

Households are heterogenous in terms of their initial endowments of capital ($K_{i,0}$) and the intertemporal elasticity of substitution (EIS), which is given by $1/(1-\gamma_i)$. Smaller values of γ_i correspond to smaller values of the EIS, and imply that the household is less willing to substitute future for present consumption. Therefore, the supply function of labor depends on γ_i. The elasticity of leisure (η) is the same for all households, so they all display the same tradeoff between consumption and leisure, but the elasticity of substitution between them is not constant, in contrast with other models found in the literature. Households of different income classes have the same rate of time preference, but in the numerical experiments, an alternative formulation explores the case in which it varies across household types.

The endowment of hours of each household is normalized to be equal to one unit, which is allocated to leisure (l_i) or work (L_i): $L_i = 1 - l_i$. Recalling the discussion in Chapter 2, the Romer-type production function considers a broad concept of capital, defining it as an amalgam of human and physical capital, and income from labor is the payment for raw labor (L_i) and does not include the returns associated with skills. The household's gross income is, then, the sum of capital income and the income from “raw labor”.[91]

The model here adopts a progressive tax schedule that generalizes the one designed by Guo and Lansing (1998), and used in Chapter 2 and in Carneiro et al. (2022), in order to reproduce more accurately the one observed empirically. The extension proposed here is to consider a third parameter, in addition to the two of the original specification, as follows:

$$\tau_i \equiv \rho - \zeta\,(y_i)^{-\phi} \tag{3.1a}$$

where τ_i is the tax rate, $y_i \equiv Y_i/Y$ is household *i* income *relative* to the average income. Note that the average y_i is 1, and that $\sum_1^N y_i = N$, and there are three parameters: the intercept (ρ), the scale parameter (ζ), and the progressivity parameter (ϕ).[92] The equation (3.1a) indicates the departure of the rate from its asymptotic value ρ, to which it tends when income increases without bound. For our policy exercises it is important to

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[91] See Mankiw, Romer, and Weil (1992) and Barro, Mankiw, and Sala-i-Martin (1995) for further discussions.

[92] It is worth noting that the parameter ζ is called scale in this chapter, unlike the previous chapter. This change in terminology is motivated by the introduction of an intercept ρ in the tax function that is now responsible for defining the level of income tax.

note that the schedule shifts down, i.e. the tax rate decreases for each income class with an increase of ζ. Also, if there is no progressivity ($\phi = 0$) the schedule is flat, and the tax rate is independent of the agent's relative income ($\tau_i \equiv \rho - \zeta$). If $\phi > 0$, the tax rate is higher for households with larger relative income. The tax rate on marginal income (${\tau_i}^m$) depends on ϕ:

$$ {\tau_i}^m \equiv \frac{\partial(\tau_i Y_i)}{\partial Y_i} = \rho - (1-\phi)\zeta(y_i)^{-\phi} \tag{3.1b} $$

The Guo and Lansing (1998) is a special case of this function for $\rho = 1$. The more general specification proposed here, with $\rho \neq 1$, has not been used before in the literature, and fits the data much better than the restricted formulation. Further, the flexibility to set ρ has a crucial importance in reproducing the tax rate for high relative incomes, where the restricted formulation yields a marginal tax rate that is much larger than that observed for the top bracket of the U.S. tax scheme. Their formulation also tends to overestimate the average tax rate paid by the lowest quintile, as can be seen by using the function and the parameters estimated by Chen and Guo (2013) to calculate it, and comparing with the observed rate.[93] Thus, ρ is set as the top marginal tax bracket that a household can fall into.[94] However, there is a need to restrict on the range of values the parameters can take to ensure that the tax and the marginal tax rates satisfy the relevant economic conditions, $\tau_i \geq 0$, ${\tau_i}^m < 1$, and ${\tau_i}^m \geq \tau_i$, both during the transition and in the steady-state. Therefore, the parameters of the tax function (3.1a) must also satisfy the following restrictions: $0 < \zeta < 1$; $0 < \rho \leq 1$; and $0 \leq \phi < 1$. [95]

There are alternative formulations of the tax schedule in the literature, and the main one is Li and Sarte (2004) which, however, has some drawbacks. It implies an overly steep tax rate schedule, [96] and requires the imposition of restrictions on the range of

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[93] Setting $\rho = 1, \phi = 0.0634, \zeta = 0.7973$ and considering the average income by quintile reported in CBO database would imply that an average person in the lowest quintile income pays a total tax around of 12%. This tax rate is much higher than the observed one, especially in the recent years (7.9% from 1987 to 2005, and 1.8% from 2006 to 2017).

[94] None of the other papers that adopt the formulation in Guo and Lansing (1998), cited in the text, consider the extension proposed here.

[95] Lloyd-Braga, Modesto and Seegmuller (2008) and K&T (2016) also impose similar restrictions on the parameters of their formulation to meet those conditions.

[96] The tax schedule in Li and Sarte (2004) is $\tau_i \equiv \zeta\ (y_i)^{\phi}$. Note that the role of the parameters is different than in (3.1a), an increase in ζ implies an increase in the tax rate, as opposed to the formulation used here, where it implies a decrease. To see that is overly steep, note that, using the parameters they estimate, the tax rate would be equal to one when $y_i = 26.7$ and $\tau_i^m = 1$ when $y_i = 12.68$. The latter implies zero net marginal income for households above that level of relative income, which is inconsistent with the US tax code.

allowed of incomes and there is the need to handle the possibility of occurrence of corner solutions. The latter are not necessary with the Guo and Lansing (1998) formulation because $\tau_i \to 1$ as $y_i \to \infty$.

Households choose the time path of consumption, leisure and capital to maximize the present value of utility subject to the following capital accumulation constraint. This framework also extends K&T slightly by including capital depreciation at an instantaneous rate δ, because this turns out to be important in the dynamics of the numeric simulations, and the public transfers ${G_i}^{TR}$ received by agent i:

$$\dot{K}_i = (1 - \tau_i)[rK_i + \omega K(1 - l_i)] - \delta K_i - C_i + {G_i}^{TR} \tag{3.2}$$

The solution of the optimal control problem yields the following system of first order equations:

$$ {C_i}^{\gamma_i - 1} {l_i}^{\eta\gamma_i} = \lambda_i \tag{3.3a}$$

$$\eta {C_i}^{\gamma_i} {l_i}^{\eta\gamma_i - 1} = (1 - {\tau_i}^m)\omega K \lambda_i \tag{3.3b}$$

$$(1 - {\tau_i}^m)\, r - \delta = \beta - \frac{\dot{\lambda}_i}{\lambda_i} \tag{3.3c}$$

where λ_i is the household i's shadow value of capital. Equation (3.3c) shows how the marginal income tax rate affects its growth rate $(\dot{\lambda}_i/\lambda_i)$ and, thereby, the capital accumulation decision of the household.

In addition to these marginal conditions, the optimal paths must satisfy the transversality condition, that the present value of the asymptotic capital holdings of each household is null.

$$\lim_{t\to\infty} \lambda_i K_i e^{-\beta t} = 0 \tag{3.4}$$

The long-run growth rate of aggregate capital and consumption will converge to a common value $\tilde{\psi}$, and (3.4) reduces to:

$$(1 - {\tau_i}^m) r > \tilde{\psi} \tag{3.5}$$

The aggregation rules of income, capital and leisure, and clearance of the aggregate labor and capital markets, are as in Chapter 2 – equations (2.11a) to (2.11c), and, corresponding to these aggregates we define the average and marginal economy-wide tax rates as weighted averages of the individual household rates, where the weights are, respectively, their relative income and their relative leisure:

$$\bar{\tau} = \frac{1}{N}\sum_{i=1}^{N} \tau_i \cdot \left(\frac{Y_i}{Y}\right) = \frac{1}{N}\sum_{i=1}^{N} \tau_i \cdot y_i = \frac{1}{N}\sum_{i=1}^{N} y_i[1-\zeta(y_i)^{-\phi}] \tag{3.6a}$$

$$\bar{\tau}^m = \frac{1}{N}\sum_{i=1}^{N} \tau_i{}^m. \left(\frac{l_i}{l}\right) = \frac{1}{N}\sum_{i=1}^{N} [1-(1-\phi)\zeta(y_i)^{-\phi}]. \left(\frac{l_i}{l}\right) \tag{3.6b}$$

There is no public debt and the government maintains a balanced budget, and like in García-Peñalosa and Turnovsky (2015), the government budget restriction is:

$$G^c + G^{TR} = (g^c + g^{tr}) \cdot F(K,L) = \frac{1}{N}\sum_{i=1}^{N} \tau_i \, Y_i \tag{3.7}$$

where g^c and g^{tr} are, respectively, the share of government consumption and of public transfers in total output and are entirely financed by the income tax. Regarding the lump-sum transfers, the model allows the rebate of different proportions of the average transfers to each quintile ($G_i{}^{TR} = \mu_i G^{TR}$). This feature turns out to be important to characterize an economy where households do not share equally the public transfers, and has implications for the allocation of time to raw labor, as will be discussed in section 4.

3.3 Equilibrium

Household i's relative gross income y_i before tax and transfers is related to its factor supply as follows:

$$y_i = \frac{Y_i}{Y} = \frac{rk_i + (1-l_i)\omega}{r + (1-l)\omega} = (1-\alpha)k_i + \alpha\,\frac{(1-l_i)}{(1-l)} \tag{3.8a}$$

Household i's relative income net of taxes, before transfers, is denoted $y_i{}^a$ and is calculated as:

$$y_i{}^a = (1-\tau_i)y_i \tag{3.8b}$$

Taking the time derivative of (3.8a) yields the dynamic constraint:

$$\dot{y}_i = (1-\alpha)\dot{k}_i - \alpha\left(\frac{1}{1-l}\right)\dot{l}_i + \alpha\,\frac{(1-l_i)}{(1-l)^2}\dot{l}. \tag{3.8c}$$

Substituting for λ_i from (3.3a) in (3.3b) shows that consumption (C_i) and effective leisure (Kl_i) are linearly related:

$$C_i = (1 - {\tau_i}^m)\frac{\omega}{\eta}Kl_i \tag{3.9}$$

Taking logs and the derivative with respect to time, while taking into account that ${\tau_i}^m$ depends on y_i (equation 3.1b), yields the relation between the rates of growth of consumption and effective leisure:

$$\frac{\dot{C}_i}{C_i} - \left(\frac{\dot{l}_i}{l_i} + \frac{\dot{K}}{K}\right) = \frac{\omega_l \dot{l}}{\omega} - \phi\frac{(\rho - {\tau_i}^m)}{(1 - {\tau_i}^m)}\frac{\dot{y}_i}{y_i} \tag{3.10}$$

where $\omega_l = \partial\omega/\partial l$.

Taking logs and the derivative with respect to time of (3.3a) and combining the resulting equation with (3.3c) yields:

$$(\gamma_i - 1)\frac{\dot{C}_i}{C_i} + \eta\gamma_i\frac{\dot{l}_i}{l_i} = \beta - (1 - {\tau_i}^m)r + \delta \tag{3.11}$$

Substituting (3.9) into (3.2), the household capital accumulation constraint implies:

$$\dot{K}_i = (1 - \tau_i)Y_i - (1 - {\tau_i}^m)\frac{\omega}{\eta}Kl_i - \delta K_i + \mu_i G^{TR} \tag{3.12}$$

The non-linear state transition equations such as (3.12) indicate the nature of the complications introduced by the progressive tax structure. With a flat tax rate schedule $(\phi = 0)$ $\tau_i = {\tau_i}^m = \tau$, the aggregation across agents is independent of the income distribution, and the dynamics can be studied recursively by first deriving the aggregate equilibrium dynamics, and then determining how the factor returns it generates affects the income distribution, as shown by Garcia-Peñalosa and Turnovsky (2008, 2011). However, with progressivity, there is interaction between the tax schedule and the income distribution, and the equilibrium aggregates and their distribution among households become jointly determined. The problem with only two agents is analytically tractable, as shown in K&T, but this is not the case here, where there are five types of households. Therefore, this study relied on numerical simulations of the calibrated model to perform sensitivity analysis with respect to the main parameters to explore the nature of the equilibrium, and found that a unique stable transitional path obtained in all cases.

Aggregating (3.12) for all households, and using the definitions of $\bar{\tau}$ and $\bar{\tau}^m$ in equations (3.6a) and (3.6b), yields:

$$\dot{K} = (1 - \bar{\tau})Y - (1 - \bar{\tau}^m)\frac{\omega}{\eta}Kl - \delta K + G^{TR} \tag{3.13}$$

Combining equations (3.2) and (3.13) with the definitions of the average output and the marginal physical product of factors, produces the differential equation that describes the path of $k_i = K_i/K$:

$$\dot{k}_i = \left\{(1 - \tau_i)[rk_i + (1 - l_i)\omega] - (1 - {\tau_i}^m)\frac{l_i}{\eta}\omega + \mu_i\, g^{TR}A(1 - l)^\alpha\right\} - \\ \left\{(1 - \bar{\tau})[r + (1 - l)\omega] - (1 - \bar{\tau}^m)\frac{l}{\eta}\omega + g^{TR}A(1 - l)^\alpha\right\}k_i \qquad i = 1, \dots, N \tag{3.14}$$

Finally, using (3.11) and (3.13) to substitute for $\dot{C}_i/C_i$ and $\dot{K}/K$, respectively, in equation (3.10) yields:

$$(1 - \bar{\tau})[r + (1 - l)\omega] - \delta - (1 - \bar{\tau}^m)l\frac{\omega}{\eta} + g^{TR}A(1 - l)^\alpha + \frac{\beta - (1 - {\tau_i}^m)r + \delta}{1 - \gamma_i} \\ = \phi\frac{(\rho - {\tau_i}^m)}{(1 - {\tau_i}^m)}\frac{\dot{y}_i}{y_i} - \left(\frac{1 - \gamma_i(1 + \eta)}{1 - \gamma_i}\right)\frac{\dot{l}_i}{l_i} - \frac{\omega_l\dot{l}}{\omega} \tag{3.15}$$

The evolution of (relative) wealth can be seen comparing the individual and aggregate growth rates of capital, denoted respectively $\psi_i(t) = \dot{K}_i/K_i$ and $\psi(t) = \dot{K}/K$, which can be derived from (3.12) and (3.13):

$$\psi_i(t) = \frac{A(1 - l)^{\alpha - 1}}{k_i}\left[(1 - \tau_i)(1 - l)y_i - (1 - {\tau_i}^m)\alpha\frac{l_i}{\eta} + \mu_i\, g^{TR}(1 - l)\right] - \delta \tag{3.16}$$

$$\psi(t) = A(1 - l)^{\alpha - 1}\left[(1 - \bar{\tau})(1 - l) - (1 - \bar{\tau}^m)\alpha\frac{l}{\eta} + g^{TR}(1 - l)\right] - \delta \tag{3.17}$$

In the long-run steady-state $\psi_i(t)$ and $\psi(t)$ will converge to a common rate $\tilde{\psi}$. The rate of growth of output $\psi_y(t) = \dot{Y}/Y$ can be obtained from the rate of growth of physical capital $\psi(t)$, by differentiating the log of equation (3.1) w.r.t. time:

$$\psi_y(t) = \psi(t) - \alpha\,\dot{l}(t)/\big(1 - l(t)\big) \tag{3.18}$$

The system of equations consisting of the $N - 1$ accumulation equations (3.14), N equations (3.15), $N - 1$ relative (gross) income equations (3.8a), and the aggregations defined in the previous chapter gives the equilibrium dynamic path of the economy. The next section describes the steady stated of the dynamic system and the following one uses the numeric solution of a calibrated version of the model to discuss the policy implications of tax reform.

In the steady state, all endogenous variables are constant ($\dot{k}_i = \dot{y}_i = \dot{l}_i = \dot{l} = 0$) and, hence, using (3.14), (3.15) and (3.8c) one obtains the system of equations for the steady state:

$$\left\{(1-\tau_i(\tilde{y}_i))\left[r(\tilde{l})\tilde{k}_i + \omega(\tilde{l})(1-\tilde{l}_i)\right] - (1-\tau_i{}^m(\tilde{y}_i))\tilde{l}_i\,\frac{\omega(\tilde{l})}{\eta} + \mu_i\, g^{TR}A(1-\tilde{l})^{\alpha}\right\} =$$

$$\tilde{k}_i\left\{(1-\ \bar{\tau})\left[r(\tilde{l}) + (1-\tilde{l})\omega(\tilde{l})\right] -\ (1-\bar{\tau}^{\,m})\tilde{l}\,\frac{\omega(\tilde{l})}{\eta} + g^{TR}A(1-\tilde{l})^{\alpha}\right\} \qquad (3.19a)$$

$$\tilde{\psi} = \frac{(1-\tau_i{}^m(\tilde{y}_i))r(\tilde{l}) - \beta - \delta}{(1-\gamma_i)} =$$

$$(1-\ \bar{\tau})\left[r(\tilde{l}) + (1-\tilde{l})\omega(\tilde{l})\right] - \delta -\ (1-\bar{\tau}^{\,m})\tilde{l}\,\frac{\omega(\tilde{l})}{\eta} + g^{TR}A\left(1-\tilde{l}\right)^{\alpha} \qquad (3.19b)$$

$$\tilde{y}_i = (1-\alpha)\tilde{k}_i +\ \alpha\frac{(1-\tilde{l}_i)}{(1-\tilde{l})} \qquad (3.19c)$$

$$\frac{1}{N}\sum_{i=1}^{N}\tilde{y}_i = 1 \qquad \frac{1}{N}\sum_{i=1}^{N}\tilde{l}_i = \tilde{l} \qquad \frac{1}{N}\sum_{i=1}^{N}\tilde{k}_i = 1 \qquad (3.19d)$$

Equation (3.19a) shows the steady-state labor market equilibrium condition which indicates that the long run capital holdings of each income class $(\tilde{k}_i)$ depend on its leisure $(\tilde{l}_i)$, and on the progressive tax rate on income (τ_i), as well as on the averages of these variables over all income classes, $\tilde{l}$, $\bar{\tau}$. The discussion below indicates how some of these interactions affect the income distribution.

First, the wealthier households enjoy a larger level of leisure relative to that of poorer households in the long run, as expected from the empirical literature.[97] This is mostly an implication of equation (3.3a) and the fact that wealthier households have a relatively lower marginal utility of wealth.

Second, households that have relatively larger EIS, i.e. larger willingness to substitute future for present consumption, have a larger steady-state relative capital $(\tilde{k}_i)$. To show this, consider a simplified economy with only two types of households, $i =$ 1 and 2, and compare their equilibrium growth rates using equation (3.19b):

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[97] As highlighted by García-Peñalosa and Turnovsky (2015) in a Ramsey model with elastic labor supply there is a positive relationship between leisure and capital, since leisure and consumption are Edgeworth complements.

$$\tilde{\psi} = \frac{[1 - \tau_1{}^m(\tilde{y}_1)]r(\tilde{l}) - \beta - \delta}{(1-\gamma_1)} = \frac{[1 - \tau_2{}^m(\tilde{y}_2)]r(\tilde{l}) - \beta - \delta}{(1-\gamma_2)} \tag{3.20}$$

and therefore,

$$\frac{(1-\gamma_1)}{(1-\gamma_2)} = \frac{\left[1 - \rho - (1-\phi)\zeta\tilde{y}_1{}^{-\phi}\right]r(\tilde{l}) - \beta - \delta}{\left[1 - \rho - (1-\phi)\zeta\tilde{y}_2{}^{-\phi}\right]r(\tilde{l}) - \beta - \delta}$$

If EIS$_1$ > EIS$_2$, i.e. $1/(1-\gamma_1) > 1/(1-\gamma_2)$, $(1-\gamma_1)/(1-\gamma_2) < 1 \Rightarrow \gamma_1 > \gamma_2$. Hence, $\rho - (1-\phi)\zeta\tilde{y}_1{}^{-\phi} > \rho - (1-\phi)\zeta\tilde{y}_2{}^{-\phi} \Rightarrow \tilde{y}_1 > \tilde{y}_2$.

Third, when the labor supply is inelastic and there is constant return to capital, the effect on the relative steady-state income $(\tilde{y}_i)$ of a decrease in either the base tax rate or its progressivity is negative (positive), for the households whose consumption is relatively less (more) sensitive to variations in the expected real interest rate. In the general case of elastic labor supply, the effect is not so clear cut because of the possibility of jumps in L. Note, however, that the long-run aggregate effects when labor supply is endogenous are actually not much different from those when it is inelastic, because the empirical estimates on the labor elasticity suggest it is small (see CBO, 2007).

3.4 Calibration for the USA before and after the TCJA 2017

This section discusses the calibration of the numeric version of equation system that characterizes the dynamic solution of the model, and represents the equilibrium of the economy, to allow the computation of its trajectory as it adjusts to parameter changes that represent the tax policy TCJA 2017 in the simulations discussed in the next section. The first subsection discusses in detail the calibration of the tax function, while the second discusses the calibration of the remaining parameters.

Before proceeding, it is useful to point out the differences between the calibration here and in the previous chapter. In chapter 2 it was designed to allow the comparison of the responses of a model economy with broad characteristics similar to those of an advanced economy to changes in progressivity under two different tax structures. In this chapter, it attempts to match more precisely the US economy before the TCJA 2017, to allow the tracking the implications of that fiscal reform for economic growth and income distribution, both in the long term and during the transition.

3.4.1 Calibration of the tax function

The crucial aspect in representing that fiscal reform is the calibration of the parameters ρ, ζ and ϕ, that represent in the model the empirical tax function (equation 1a), both before and after the implementation of the policy, while taking into account the standard deductions to household income, and the federal income tax brackets defined in the legislation. The tax code specifies that, after taking the standard deduction, the application of the marginal tax rate to each successive tranche of income, up to the tax bracket of the total income of the individual. For example, in the pre-reform scenario the average household in the middle quintile subtracts the standard deduction ($9,350), and pays a total tax of 10% on his first $13,350 plus 15% on the subsequent $37,450 plus 25% on the balance. Table 3.1 details the tax schedules before and after the tax reform.

The estimation of the parameters before and after the TCJA follows a procedure analogous to the one described in Carneiro et al. (2022). First, use the tax schedules reported in Table 3.1 to calculate the amount of income tax paid by each household quintile as described in the previous paragraph. Thereafter, sets ρ equal to the top marginal income tax rate and uses the equations (3.1a) and (3.1b) sequentially to estimate ϕ_i and ζ_i. Tables 3.2 and 3.3 report the pre- and post-reform scale and progressivity fiscal parameters. It is noteworthy that the estimated pre-reform income average tax rates paid by the head of household (column "Estimated Tax Rate" of Tables 3.2) are similar to the observed historical US federal tax rates.[98]

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[98] According to CBO data reported by the quintiles, the average Federal Taxes from 2000 to 2017 were 3.15%, 9.59%, 13.97%, 17.60% and 25.37%, for Q1 to Q5 respectively. When analyzing the differences between these tax rates and those reported in Tables 3.2, one should keep in mind that the former considers several taxes – individual income taxes, payroll taxes, corporate income tax, and excise tax – while the latter considers only the income tax rates paid by the head of household.

Table 3.1 – Head of Household Taxable Income Tax Brackets and Rates

2017		**2018**	
Standard Deduction: $ 9,350		Standard Deduction: $ 18,000	
Tax Rate	Taxable Income Bracket	Tax Rate	Taxable Income Bracket
10%	< 13,350	10%	<13,600
15%	13,351-50,800	12%	13,601-50,800
25%	50,801-131,200	22%	50,801-82,500
28%	131,201-212,500	24%	82,501-157,500
33%	212,501-416,700	32%	157,501-200,000
35%	416,701-444,550	35%	200,201-500,000
39.6%	> 444,550	37%	> 500,000

Table 3.2 – Pre-reform Tax Parameters by Quintiles (2017)

Quintile	Average Income*	Marginal Tax Rate	Estimated Taxes	Estimated Tax rate	ρ	$\hat{\phi}_i$	$\hat{\zeta}_i$
First (Q1)	$ 13,258.00	10%	$ 390.80	2.9%	0.396	0.192	0.256
Second (Q2)	$ 35,401.00	15%	$ 3,240.10	9.2%	0.396	0.192	0.257
Middle (Q3)	$ 61,564.00	25%	$ 7,306.00	11.9%	0.396	0.474	0.236
Fourth (Q4)	$ 99,030.00	25%	$ 16,672.50	16.8%	0.396	0.359	0.239
Highest (Q5)	$ 221,646.00	33%	$ 49,749.18	22.4%	0.396	0.615	0.307

*Mean income received in 2017 (CENSUS Data - available at https://www.census.gov/data/tables/ time-series/demo/income- poverty/historical- income- households.html).

Table 3.3 – Post-reform Tax Parameters by Quintiles (2018)

Quintile	Average Income*	Marginal Tax Rate	Estimated Taxes	Estimated Tax rate	ρ	$\hat{\phi}_i$	$\hat{\zeta}_i$
First (Q1)	$ 13,258.00	10%	- $ 474.20	-3.58%	0.370	0.335	0.217
Second (Q2)	$ 35,401.00	12%	$ 1,816.12	5.13%	0.370	0.216	0.263
Middle (Q3)	$ 61,564.00	22%	$ 4,232.08	6.87%	0.370	0.502	0.254
Fourth (Q4)	$ 99,030.00	24%	$ 12,475.20	12.60%	0.370	0.467	0.260
Highest (Q5)	$ 221,646.00	32%	$ 45,564.72	20.56%	0.370	0.696	0.317

*Mean income received in 2017 (CENSUS Data - available at https://www.census.gov/data/tables/ time-series/demo/income- poverty/historical- income- households.html).

The next step is to transform these quintile estimates into summary economy-wide average estimates $\hat{\phi}$ and $\hat{\zeta}$ suitable for use as the fiscal parameters in equation (3.1a) of the model. This could be done in several different ways, but here, as in Carneiro et al. (2022), this is done by minimizing the sum of squared residuals between the quintile rate calculated by the tax functions (Eqs. 3.1a and 3.1b) and the observed data, for both the corresponding marginal tax rate (column “Marginal Tax Rate”) and the rate (column “Estimated Tax Rate”) of Tables 3.2 and 3.3. The range of the parameters $\hat{\phi}_i$ and $\hat{\zeta}_i$ constitute the upper and lower constraints to estimate these average fiscal parameters. Table 3.4 reports the calibrated values of the parameters, both before and after the TCJA:

Table 3.4 – Intercept and Estimated Average Tax Parameters

	ρ	$\hat{\phi}$	$\hat{\zeta}$
Pre-Reform Economy	0.396	0.290	0.236
Post-Reform Economy	0.370	0.332	0.231

Figure 3.1 show calibrated tax functions adopting two sets of parameters: the one denoted $f(y_i)$ uses the pre-reform parameters of Table 3.4, and the other, denoted $g(y_i)$, uses the average parameters estimated by Chen and Guo (2013), which was the calibration used in chapter 2. It also displays the estimated pre-reform income tax rates paid by the head of household. The comparison of the two curves supports the progressive tax schedule adopted in this chapter, indicating that the calibration proposed here is vastly superior in its adherence to the estimated tax rates for all income brackets than the one adopted by Chen and Guo (2013).

Finally, the comparison of $f(y_i)$ with the tax function calibrated with that in Carneiro et al. (2022), denoted $z(y_i)$, in Figure 3.2 shows that both functions accurately reproduce the pre-reform tax rates for the quintiles.

Nevertheless, $f(y_i)$ emulates more closely the tax rates paid by a super-rich household than $z(y_i)$. Recall equations (3.1a) and consider, for example, the IRS data on the 400 Individual Income Tax Returns.[99] For $z(y_i)$, using the fiscal parameters of Carneiro et al. (2022), the marginal income tax rate paid by these is approximately 62%, which is much larger than the observed the top marginal rate. In turn, if the tax function is $f(y_i)$, the average marginal income tax rate paid by this group is equal to 37.7%, which is more plausible, considering the actual rate of 39.6%.

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[99] Available at https://www.irs.gov/pub/irs-soi/09intop400.pdf.

Figure 3.1 – Comparison of the tax function here with that in Chen and Guo (2013)

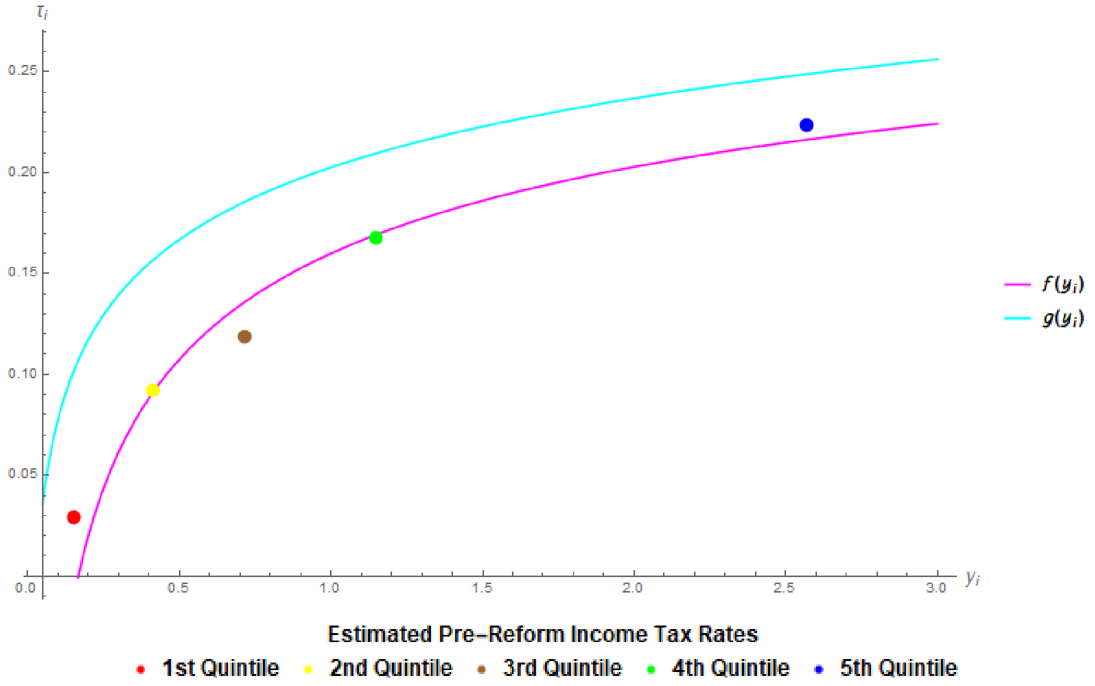
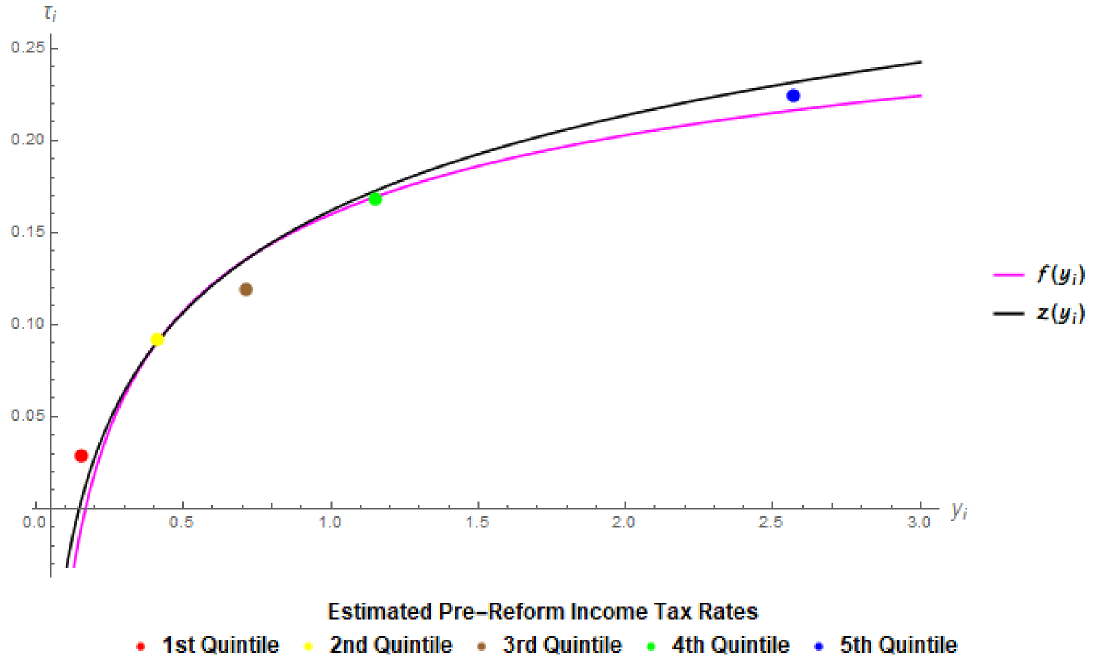


Figure 3.2 – Comparison of the tax function here with that in Carneiro et al. (2022)



3.4.2 Calibration of the other parameters

Table 3.5 summarizes the calibrated values of the parameters. The model assumes the government maintains a balanced budget, and adjusts its expenditures to the overall tax revenues by varying its consumption (g^c) while maintaining the share of public transfers (g^{TR}) at 11%, the average observed from 2010 to 2017 according to the Federal Reserve Economic Data.[100] The fraction of public transfers that accrue to each quintile relative to the average transfers (μ_i) was set as the average observed from 1976 to 2016 reported in CBO data[101], and is constant in the simulations.[102] While it might be appealing to consider variations in these ratios to investigate the responses to a redistributive policy, this study focuses on responses to tax changes, and hence avoids distributive policies through direct public transfers.

Table 3.5 – Benchmark Economy

Technology parameters	
Scale Parameter (A)	0.435
Elasticity of labor in production (α)	0.280
Preference parameters	
Elasticity of leisure (η)	0.675
Rate of Time Preference (β)	0.038
Individual Intertemporal Elasticity of Substitution ($1/(1-\gamma_i)$)	
Q1: First quintile ($1/(1-\gamma_1)$)	0.353
Q2: Second quintile ($1/(1-\gamma_2)$)	0.442
Q3: Third quintile ($1/(1-\gamma_3)$)	0.500
Q4: Fourth quintile ($1/(1-\gamma_4)$)	0.567
Q5: Highest quintile ($1/(1-\gamma_5)$)	0.694
Policy parameters and taxes	
Capital Depreciation Rate (δ)	0.100
Degree of progressivity of tax rate ($\hat{\phi}$)	0.290
Scale of tax schedule ($\hat{\zeta}$)	0.236
Intercept of tax schedule ($\hat{\rho}$)	0.396
Marginal tax rate on total income ($\bar{\tau}^m$)	21.11%
Average tax-rate on total income ($\bar{\tau}$)	17.58%
Ratio of public transfers (μ_i)	$\mu_1 = 2.6$ $\mu_2 = 1.3$ $\mu_3 = 0.6$ $\mu_4 = 0.3$ $\mu_5 = 0.2$

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[100] The Federal government current transfer payments and the Gross Domestic Product are available at https://fred.stlouisfed.org/series/W014RC1Q027SBEA and https://fred.stlouisfed.org/series/GDP .

[101] Data available at https://www.cbo.gov/publication/55413 .

[102] It turns out that the poorest quintile receives the major portion of the government transfers (around 50%) and ends up consuming more leisure than the middle quintiles.

The procedure described in the previous subsection was used to estimate the fiscal parameters in the pre-reform scenario, $\hat{\phi} = 0.290$, $\hat{\zeta} = 0.236$ and $\rho = 0.396$, which imply an average tax rate of 17.6% that is close to the one that prevailed in the period between 2000 to 2017, according to CBO data (20.3%). The tax rates for each household type are also similar to the average rates reported by CBO for each income quintile [103] as indicated in Table 3.6.

The parametrization of the technology and preference parameters are discussed below.

3.4.2.1 Technology Parameters

The value of the parameter of the Romer-type AK production function must take into consideration that the wage includes an externality proportional to the aggregate capital stock, as discussed earlier in connection with equation (2.3) of chapter 2. Therefore, as in Carneiro et al. (2022), the elasticity of raw labor (α) is set to 0.28, which is less than half of the labor share in production.[104] This is similar to 0.34, which is the value adopted by K&T, based on the exponent of labor in the Cobb-Douglas production function estimated by Mankiw et al. (1992), but is only half of the value adopted by Chen (2000). Quite similar to Carneiro et al. (2022), the scale parameter of the production function was calculated as A = 0.435 to yield an equilibrium growth rate of the economy of about 2.5% per year, which is approximately equal to the observed growth rate in the US economy recently.

Since the specification of the model assumes that capital is an amalgam of physical and human capital, as discussed in chapter 2, the estimates of Nadiri and Prucha (1996) for the depreciation rates for both physical and knowledge capital for the US economy are used, and δ is set to 0.1, as in Chen (2020). Indeed, the literature contains a wide variety of values for that parameter, but the chosen value is within the range suggested by Klenow & Rodrigues-Clare (2005) for AK models, and is consistent with those estimated by Epstein and Denny (1980) and Bischoff and Kokkelenberg (1987).

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[103] The federal tax rates to each quintile between 2000 and 2017, according to CBO data, were 25.4%, 17.6%, 14%, 9.6% and 3.1%.

[104] The labor share in the USA in 2016 was about 58%.

3.4.2.2 Preference Parameters

The individual rate of time preference (β) was set to 0.038, quite close to the average value of that parameter for rich and poor individuals in K&T, and yields a value that is within the consensus range (see, e.g., Garcia-Peñalosa and Turnovsky 2015; Chen 2020; Atolia, Papageorgiou and Turnovsky 2021). The elasticity of leisure in the utility function (η), which affects how households allocate their time between leisure and work, is set to 0.675 for an overall allocation of time to raw labor of about 37.4%, which is consistent with the revealed preference of households,[105] and is well within the range usually adopted in macroeconomic simulations.[106] This value is also consistent with the Frisch elasticity estimated by Keane (2011). These parameters, taken together, imply that labor supply varies significantly across households, and, for example, the highest quintile allocates only 11.4% of their time to providing raw labor. Although the time devoted to work by the highest quintile is significantly below the average work effort, one must recall that this is the amount of total time devoted to providing raw unskilled labor (see Rebelo, 1991), while the return to labor associated with skills is part of the return to capital.[107]

The empirical literature contains mixed evidence concerning the aggregate value of EIS. Mulligan (2002), Vissing-Jørgensen and Attanasio (2003), Fuse (2004), Gruber (2013) and Ben-Gad (2012) report values higher than one. Attanasio and Weber (1995) and Blundell, Browning and Meghir (1994) estimate it to be close to unity. The aggregate value most often encountered in macroeconomic models is $1/(1-\gamma) = 0.5$, as in Lucas (1990), Baier and Glomm (2001), Kitao (2010), Angyridis (2015) and K&T. Chatterjee and Turnovsky (2007) and Turnovsky and García-Peñalosa (2008) use $\gamma = -1.5$ (IES $=$ 0.4) which is well within the range summarized by Guvenen (2006).

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[105] In 2019, the average hours worked per week in the USA by persons who usually work full time was 42.5, according to U.S. Bureau of Labor Statistics data, available at https://www.bls.gov/cps/cpsaat22.pdf . This would be equivalent to an allocation of time to labor of around 35.4%, considering only business days as workers' endowment.

[106] As emphasized by Chatterjee and Turnovsky (2007), the labor-leisure decision is quite sensitive to the calibration of η, and macroeconomists often pin down this parameter to yield an equilibrium labor supply consistent with the empirical evidence. They set this parameter as 0.2, significantly lower than K&T and Turnovsky and García-Peñalosa (2008) that adopt 0.85 and 1.75, respectively.

[107] Further, there is an extensive literature that supports the negative relationship between wealth and labor supply (see, e.g., Holtz-Eakin et al. 1993; Algan et al. 2003; Turnovsky and García-Peñalosa 2008). This means that, due to their relatively lower marginal utility of wealth, richer individuals increase consumption of all goods, which includes leisure.

The evidence in the literature on the variation of the EIS for different income classes is scarce. Lluch, Powel and Williams (1977) estimate an extended linear expenditure (ELES) for several countries, and find representative values are 0.13 for very low income, 0.25 for low income, 0.33 for developing, and 0.5 for developed countries. The evidence they obtain on its variation for different income classes within several countries is mixed, but it is sufficient for them to conclude that it supports the conjecture that it increases with income, in line with the evidence above extracted from cross-country national income data. Attanasio and Weber (1993) estimate that the aggregate EIS varies from 0.34 to 0.48 across countries, but these estimates are most likely biased because they do not consider socio-demographic factors that vary across different cohorts. Chatterjee (1994) considers the existence of a monotonic relationship between average propensity to save (which depends on the EIS) and wealth, and shows that it influences the evolution of wealth inequality over time. Atkeson and Ogaki (1996) argue that the EIS differs between rich and poor households, being smaller for poorer ones, because they spend a larger share of their budget in the consumption of subsistence and necessary goods, which are harder to reallocate in time. Using panel data from India, they find that the differences in the EIS are significant: on average, its value for the richest and poorest six households is equal to 0.8 and 0.5, respectively. Further, by allowing the rate of time preference and the EIS to vary with wealth and income, they conclude that the former appears not to vary with wealth, while the latter varies with income, being larger for the richer households.

The calibration of the EIS for the five household types is quite similar to the one adopted in Carneiro et al. (2022)[108] and used the evidence above on the range of empirical values by setting its value for Q5 around the upper value of that range, and progressively smaller values for the other quintiles, to yield a value for Q1 close to the lowest value of that range. Hence γ_5 was set -0.44 to, which implies $\text{IES}_5 = 1/(1-\gamma_5) =$ 0.694 for the highest income class, and γ_1 was set to -1.835, implying $\text{IES}_1 = 1/(1-\gamma_1) =$ 0.353 for the poorest quintile. For the intermediate income classes, it was set to vary with equal increments between these two extremes, yielding the values reported in Table 3.5. The

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[108] The more significant change is regarding the EIS of the richest quintile and is due to the adopted tax parameters. As illustrated by Figure 3.2, the tax schedule adopted in this chapter is slightly less progressive than the one adopted in Carneiro et al. (2022) and so this change in the EIS is required to preserve the empirical adherence of the model to the observed income distribution.

implied average EIS in this economy is 0.51, which is well within the range for the aggregate value of the EIS indicated previously.

3.5 Benchmark equilibrium and policy simulations

This section discusses the benchmark equilibrium and shows simulations that represent approximately the tax policy changes implemented in 2017 in the USA. The model is well suited to assess the effects of a fiscal reform that reduces the tax burden across all classes, especially to low-income earners, and supports a counter-factual analysis for that policy. The benchmark corresponds to the business-as-usual situation and the experiments attempt to assess the results of a suitably simplified characterization of the Tax Cuts and Jobs Act (TCJA) of 2017. Two simulations are performed, the first one with the model as specified, with heterogeneity represented by variations in the EIS, and the other with an extended formulation of the model which also considers variations in the rate of time preference (RTP).

3.5.1 Benchmark equilibrium

Table 3.6 describes the initial SS equilibrium. The growth rate of 2.47% matches the GDP annual growth of the US economy in the last decade, as reported by World Bank. The variation of the allocation of time to raw labor between the quintiles reflects the variation of the marginal utility of wealth (Holtz-Eakin, Joulfaian, and Rosen, 1993; Cheng and French, 2000; Coronado and Perozek, 2003), and the poorest quintiles work significantly more than the top quintile, which allocates only 11.4% of their time to supply raw labor.[109] It is also noteworthy that households in the poorest group work fewer hours than those of the fourth and third quintile, mainly due to the large government transfers to this group.

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[109] In interpreting this figure, one must recall that a significant portion of the total time devoted to labor by the highest quintile is associated with skills and is included in the return to capital.

The lower section of Table 3.6 shows that the shares of income of the lowest and highest income quintiles is, respectively, $y_1/5 = 3.7\%$ and $y_5/5 = 51\%$, which broadly agree with the observed values of 3.08% and 51.4%, respectively[110]. It is also compared to the observed values of income before tax and transfers in 2017 provided by CBO of 3.8% and 54%, respectively.[111] The share of capital of the highest income quintile in total wealth is $k_5/5$ =68.5%, while the share of the lowest income is actually negative. The fact that the poorest income class has negative wealth is not unprecedented and unfortunately information on the distribution of wealth is sparse so it is difficult to assess the plausibility of -4.1%. One of the few studies to provide estimates of quintiles shares of household wealth is Davies et al. (2011). In the case of the US their estimated quintile shares are -0.1%, 1.2%, 4.5%, 11.8%, and 82.6%. But despite the differences across the quintile distributions – in large part because there the capital is composed only of physical goods, but here it also includes knowledge – our estimate of the overall GINI wealth coefficient is not too distant from the Davies et al. (2011) estimate.

The GINI coefficient calculated below summarizes the income distribution and is useful to trace the time path of inequality in the economy:

$$GINI = \frac{N+1}{N} - \frac{2\sum_{i=1}^{N}(N+1-i)y_i}{N\sum_{i=1}^{N} y_i} \tag{3.21}$$

It yields a value of 0.434 for the benchmark economy, which is slightly larger than indicated by the latest available data for US according to World Bank (0.41) and OECD (0.39).[112] The GINI coefficient for wealth is analogous to that for income, and its value is 0.67, which is similar to the actual values. Therefore, the model emulates the actual income inequality in the US economy quite well.[113]

Table 3.6 – Initial Steady-State Equilibrium

Aggregate Growth Rate of Capital ($\tilde{\psi}$)	2. 47
Labor Supply	
Q1: First quintile $(1-l_1)$	0.442
Q2: Second quintile $(1-l_2)$	0.463
Q3: Third quintile $(1-l_3)$	0.453
Q4: Fourth quintile $(1-l_4)$	0.380
Q5: Highest quintile $(1-l_5)$	0.114
Average	0.371

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[110] According to CENSUS Data of mean income received in 2017, available at https://bit.ly/mean_income.

[111] Available at: https://www.cbo.gov/publication/57061.

[112] World Bank data available at bit.ly/3G2D2DN and OECD data available at bit.ly/oecd_data .

[113] This conclusion is robust to the differences in the concept of capital in the model, which includes human capital, since its distribution among the household types is, indirectly, the same as that of physical capital.

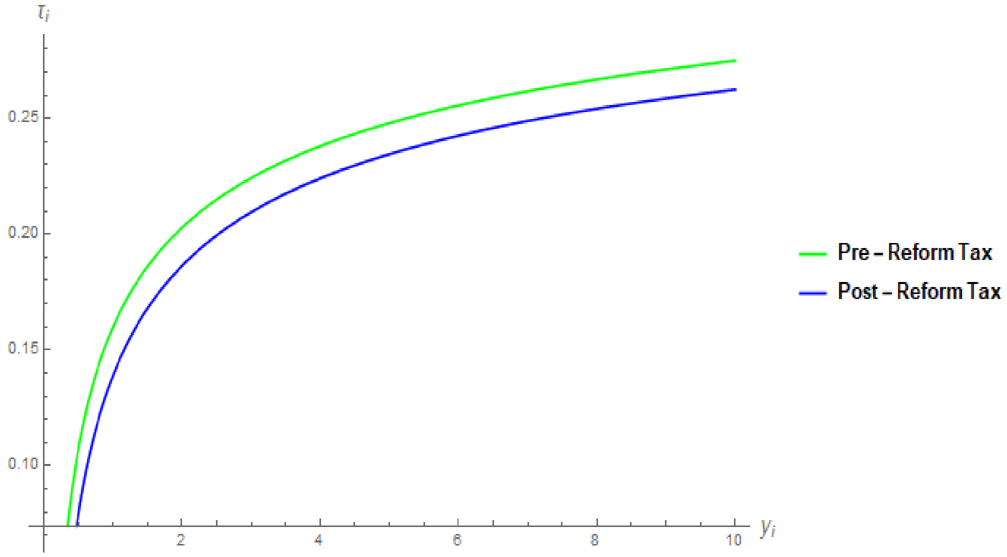
Individual Tax Rate		
Q1: τ_1	1.2%	
Q2: τ_2	9.5%	
Q3: τ_3	13.4%	
Q4: τ_4	16.8%	
Q5: τ_5	21.6%	
Marginal Tax Rate		
Q1: ${\tau_1}^m$	12.3%	
Q2: ${\tau_2}^m$	18.2%	
Q3: ${\tau_3}^m$	21.0%	
Q4: ${\tau_4}^m$	23.4%	
Q5: ${\tau_5}^m$	26.8%	
Capital Shares	k_i	$[(k_i/N)\cdot 100]$
Q1 (k_1)	-0.21	-4.1%
Q2 (k_2)	0.12	2.3%
Q3 (k_3)	0.49	9.9%
Q4 (k_4)	1.11	23.5%
Q5 (k_5)	3.42	68.4%
Income Shares	y_i	$[(y_i/N)\cdot 100]$
Q1 (y_1)	0.19	3.7%
Q2 (y_2)	0.43	8.7%
Q3 (y_3)	0.70	13.9%
Q4 (y_4)	1.13	22.7%
Q5 (y_5)	2.55	51.0%

3.5.2 Effects of TCJA 2017 in an economy with one source of heterogeneity

This section simulates the implementation of the TCJA 2017 by adjusting the parameters of the tax schedule, as described in the previous section, which amounts to a decrease the scale parameter ζ from 0.236 to 0.231, an increase in the degree of progressivity parameter ϕ from 0.290 to 0.332 and reduction of the intercept parameter ρ from 0.396 to 0.37. The decrease in ρ represents a reduction in the marginal tax rate of the highest quintile, and implies an overall decline in the tax schedule that favors all households. The small decrease in ζ indicates that the reduction with respect to income on the asymptotic tax rate for the lower income classes is slightly smaller after the reform. On the other hand, this reduction of ζ, besides being inversely proportional to the household's relative income, also depends on the degree of progressivity ϕ, which increases in the post-reform (see equation 3.1a). Hence, the decrease in ζ means that the gap between the highest and lowest marginal tax paid by a household in the post-reform is narrower than in the pre-reform, while the increase in ϕ means that the poorest quintiles will be closer to the lower bracket and the richest quintiles will be closer to the upper bracket.[114] In sum, this fiscal reform reduced the tax burden for all taxpayers represented in the model as shown by Figure 3.3, but implied asymmetric reductions in the tax rates that favor the poorer quintiles.

The simulations here, and in the next section, assume that the tax change of the reform is permanent, and that the economy will converge over time to a new steady state at an endogenously determined pace. Table 3.7 summarizes the changes on impact, in the medium term (after 10 years) and in the long run, of the policy. The values shown there are proportional deviations, except for the growth rates of capital, where the change is in percentage point changes, and the tax rates, which are shown in absolute values.[115] Figure 3.4 displays the trajectories of the main endogenous variables for each quintile.

Figure 3.3 – Comparison of Pre- and Post-Reform Tax Schedules



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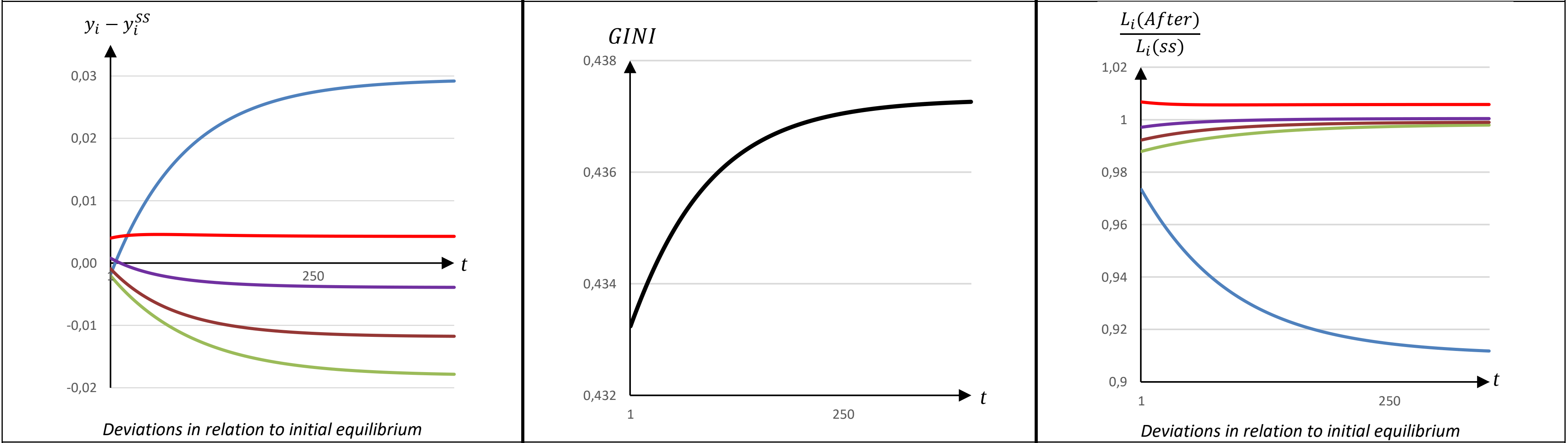
[114] This post-reform calibration captures the changes introduced by the TCJA 2017, since in practice the difference between the highest and lowest marginal tax bracket in the pre- and post-reform is 29.6 p.p. and 27 p.p respectively., as reported in Table 3.1. Also, comparing the third column in both Table 3.3 and 3.4, one can note that the marginal tax rate for Q2-Q4 is 3 p.p. closer to the lower bracket after the reform while for Q5 is 1.6 p.p. closer to the upper bracket. In the case of the poorest quintile, the benefit came through the standard deduction, which practically doubled in value and granted to this group a negative income tax.

[115] The discrete time version of the model programmed with the software GAMS (General Algebraic Modeling System) described in GAMS (2013). As emphasized by Wang (1996), it easier to run numerical experiments in a discrete-time model, and the results usually approximate satisfactorily the results of the infinite horizon when it is run for a large enough number of periods. The simulations here consider a horizon of T = 480 years, and the results at t=200 are taken to represent the long run.

Table 3.7 – Impact and Long Run Effects of TCJA 2017

	Impact	**After 10 periods**	**Long-run**
Δ[Growth rate, ψ]			
Aggregate	0.161	0.161	0.164
Q1	0.128	0.138	0.164
Q2	0.052	0.068	0.164
Q3	0.114	0.119	0.164
Q4	0.139	0.141	0.164
Q5	0.177	0.175	0.164
Δ[Labor Allocation, L]			
Aggregate	-0.0019	-0.0019	-0.0017
Q1	0.0030	0.0028	0.0026
Q2	-0.0013	-0.0011	0.0002
Q3	-0.0035	-0.0032	-0.0004
Q4	-0.0046	-0.0043	-0.0007
Q5	-0.0030	-0.0037	-0.0102
Average Tax Rate, τ			
Aggregate	15.56%	15.56%	15.59%
Q1	-3.11%	-3.09%	-3.09%
Q2	6.51%	6.50%	6.40%
Q3	10.95%	10.94%	10.81%
Q4	14.83%	14.82%	14.73%
Q5	20.07%	20.07%	20.14%
Marginal Tax Rate, τ^m			
Aggregate	19.67%	19.67%	19.66%
Q1	10.21%	10.22%	10.22%
Q2	16.63%	16.63%	16.56%
Q3	19.60%	19.59%	19.51%
Q4	22.19%	22.19%	22.12%
Q5	25.69%	25.69%	25.73%
Δ[Income GINI]	-0.116	-0.080	0.288
Δ[Wealth GINI]	0.000	0.058	0.651
Δ[Income Share, y_i]			
Q1	0.0008	0.0008	0.0009
Q2	0.0002	0.0000	-0.0008
Q3	-0.0002	-0.0004	-0.0024
Q4	-0.0004	-0.0007	-0.0036
Q5	-0.0004	0.0002	0.0059
Δ[After-tax Inc. Share, ${y_i}^a$]			
Q1	0.0018	0.0018	0.0019
Q2	0.0010	0.0009	0.0001
Q3	0.0003	0.0001	-0.0017
Q4	-0.0005	-0.0007	-0.0033
Q5	-0.0026	-0.0021	0.0030
Δ[Wealth Share, k_i]			
Q1	0.000	0.0001	0.0002
Q2	0.000	-0.0002	-0.0016
Q3	0.000	-0.0004	-0.0036
Q4	0.000	-0.0004	-0.0052
Q5	0.000	0.0009	0.0102

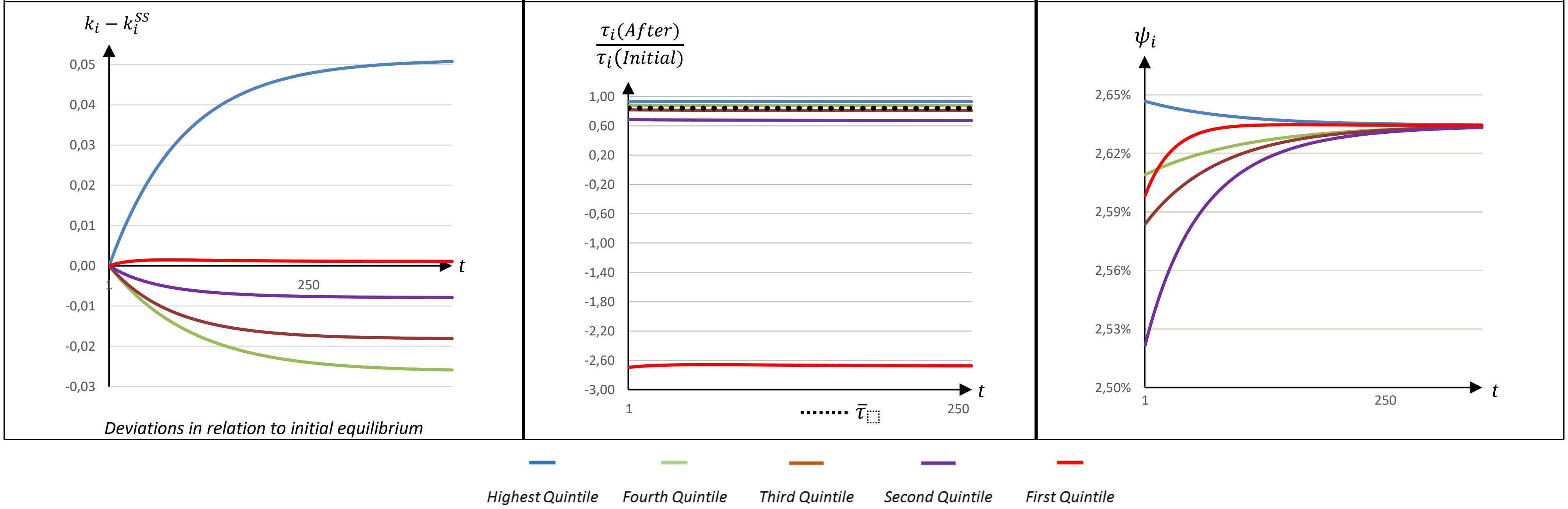
Figure 3.4 – Dynamic Effects of the TCJA 2017



(a) Effects on Income Distribution

(b) Effects on Income GINI Coefficient

(c) Effects on Labor Supply



(d) Effects on Capital Distribution

(e) Effects on Average Progressive Tax

(f) Individual Growth Rates of Capital

The second section of Table 3.7 shows that the labor supply of Q5 decreases by about 3% on impact and that this reduction increases throughout the transition. The immediate effect on labor supply is also negative for Q2-Q4 but is positive for the poorest quintile. During the transition, however, the hours devoted to work of Q2-Q4 increase slightly (see Figure 3.4c). In the long run, although Q1-Q2 supply more labor than in the initial steady-state, there is a small decline in overall employment, which highlights the empirically well-established sensitivity of labor supply to the progressivity of the tax structure (e.g., Koyuncu, 2011; Chen, 2020).

Accordingly, only two groups increase their relative long-run gross income share in response to the tax cut: Q1 and, especially, Q5.[116] As shown in the fifth and sixth section of Table 3.7, the tax reform mildly increases income inequality because the long-run relative income of Q5 increases in detriment of the middle quintiles, Q2-Q4, while Q1 long-run relative income is slightly higher than that of benchmark level after an increase on impact, which continues throughout the transition. The trajectory of the GINI coefficient for income summarizes the effect on inequality of the policy: after a small drop on impact, rises from 43.4 to 43.7 (see Figure 3.4b). The fiscal reform increases wealth inequality further than income inequality, as the ratio of the GINI coefficients for income and wealth decreases slightly in the long run.

In summary, the simulated TCJA increases the aggregate growth rate of the economy, which rises by 0.16 p.p., as well as inequality, as indicated above, in spite of the fact that it entails an increase in the progressivity of the tax schedule. The tax cut policy results in a growth-inequality tradeoff since the rate of capital accumulation of the richest quintile increases in response to this fiscal policy most rapidly than that of the other quintiles. If, however, the tradeoff is assessed in terms of the after-tax income distribution, it turns out not to be costly from a distributional perspective, since the GINI coefficient for net income is unchanged (40.6).

3.5.3 Effects of TCJA 2017 in an economy with two sources of heterogeneity

This section discusses the simulation of the TCJA 2017 by considering two types of household heterogeneity: differences in the EIS and in the rate of time preference (RTP). The

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[116] From an after-tax income standpoint, the seventh section of Table 3.7 shows that the bottom quintile increases more substantially their relative net income because of the TCJA implied by the model, recalling that this group is subject to a negative income tax.

literature contains a large number of studies that consider only one of these sources of heterogeneity (see, e.g., Uzawa 1968; Lawrance 1991; Chatterjee 1994), but only a few allow both the RTP and EIS to differ across different income groups (Ogaki and Atkeson 1997). The model described in the previous section is extended to admit that agents may also differ with respect to their RTP, and the comparison of the results of these two models helps in identifying the effects of considering these two sources of heterogeneity, and contributes to that literature.[117] Table 3.8 reports the parameterization.

The discussion following equation (3.20) showed that the ranking of steady state income of the different household groups $(\tilde{y}_i)$ is the result of the differences in their intertemporal choices under a progressive tax structure, depending then on both the individual EIS (γ_i) and the overall RTP (β). [118] When the RTP also varies between households (β_i), that analytic proof of the direction of that effect breaks down and its evaluation becomes dependent on simulations of the numeric version of the model.

The papers in the literature that adopt the quintile disaggregation and consider the impatience as the source of heterogeneity, e.g. Li and Sarte (2004) and Angyridis (2015), specify a very tight range of variation across agents, less than 2% from the highest to lowest quintiles.[119] The calibration adopted in this section is in line with these parsimonious schedules, adopting values evenly distributed across the quintiles so that the difference between household i's and household $(i+1)$'s RTP is 2%. This yields a RTP range from 0.03952 to 0.03648, as the arithmetic average of the rates of time preference is made equal to that in the original model (0.038), allowing the comparison of the simulations of the two versions of the model. The calibration of the extended model with these small variations of impatience rates is explained, firstly, by the scarce empirical evidence regarding the difference in RTP between rich and poor households. Therefore, it is plausible to suppose that variations in RTP across individuals are very slight, probably within statistical margins of error. Second, since the extended model assumes that there are two sources of heterogeneity, it is inevitable that, to preserve the empirical adherence to the observed income distribution in the US economy, the variation in

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[117] The empirical literature that estimates the differences in time preferences across agents is scarce and far from a consensus. For example, Ogaki and Atkeson (1997) find that RTP does not change amongst rich and poor households while Gourinchas and Parker (2002) identify that RTP may change over household's life. Tanaka, Camerer and Nguyen (2006) support the view that the RTP vary with income, resulting that a rich individual is more patience than a poor one.

[118] See Li and Sarte (2004) and Turnovsky and Koyuncu (2016) for further discussion of how intertemporal choices affect the equilibrium income, and the proof that the more patient individual ends up with more capital and income.

[119] The impatience rates are represented in those papers by discount factors instead of RTP.

RTP and EIS is relatively narrower compared to models in which only one of these parameters varies across households.

The calibration of the EIS of the different household types used a methodology similar to that used in the original model and yield a value for the average EIS quite close to the one before (0.5). This implies values for the EIS that vary across households in a slightly narrower range than in the original model, 0.359 – 0.663 rather than 0.353 – 0.694. The value of the other parameters of the original model are not changed, except for the scale parameter (A), that is adjusted slightly to make the growth rate of the economy match the benchmark growth rate.

Table 3.8 - Parameter values of the extended model

Technology parameters	
Scale Parameter (A)	0.435
Elasticity of labor in production (α)	0.28
Preference parameters	
Elasticity of leisure (η)	0.675
Rate of Time Preference (β)	
Q1: First quintile	0.03952
Q2: Second quintile	0.03876
Q3: Third quintile	0.03800
Q4: Fourth quintile	0.03724
Q5: Highest quintile	0.03648
Individual Elasticity of intertemporal substitution($1/(1-\gamma_i)$)	
Q1: First quintile ($1/(1-\gamma_1)$)	0.359
Q2: Second quintile ($1/(1-\gamma_2)$)	0.445
Q3: Third quintile ($1/(1-\gamma_3)$)	0.497
Q4: Fourth quintile ($1/(1-\gamma_4)$)	0.554
Q5: Fourth quintile ($1/(1-\gamma_5)$)	0.663
Policy parameters and taxes	
Capital Depreciation Rate (δ)	0.100
Degree of progressivity of tax rate ($\hat{\phi}$)	0.332
Scale of tax schedule ($\hat{\zeta}$)	0.231
Intercept of tax schedule ($\hat{\rho}$)	0.370
Marginal tax rate on total income ($\bar{\tau}^m$)	21.11%
Average tax-rate on total income ($\bar{\tau}$)	17.58%
Ratio of public transfers (μ_i)	$\mu_1 = 2.6$ $\mu_2 = 1.3$ $\mu_3 = 0.6$ $\mu_4 = 0.3$ $\mu_5 = 0.2$

Table 3.9 summarizes the benchmark equilibrium for this version of the model, which is virtually identical to the case in which the EIS is the only source of preference heterogeneity.

This ensures that the policy simulation exercises based on deviations from the benchmark trajectory of the two versions of the model are comparable. Table 3.10 displays the results of simulation of the TCJA of 2017, characterized by Table 3.4, and shows the changes it produces on impact, and in the medium and the long run, relative to the initial steady state. Figure 3.5 illustrates the transitional dynamics. Their comparison with Table 3.7 and Figure 3.4, respectively, shows the differences in the effect of the policy in the two versions of the model.

The immediate increase in the rate of capital accumulation of the top quintile is slightly smaller in the extended model (0.165 p.p.), than in the original model (0.177 p.p.), so it is closer to the average growth rate. This is due, in part, to the smaller difference in the EIS of the household groups in the former, relative to the latter, indicated earlier.[120] The lower rate of capital accumulation of Q5 leads to a smaller increase its relative wealth throughout the transition, and in the long run it owns a fraction of total wealth that is 0.63 p.p. higher than in the pre-reform equilibrium. This compares with an increase of 1.0 p.p. in the original model, described in the previous section. The savings of the poorest quintiles increases *vis-à-vis* the original model because they are now relatively less patient, compared to the average household, and are more willing to invest. For Q1, the rate of capital accumulation is more distant from the economy-wide rate than in the original model (0.08 p.p. versus 0.13 p.p) and the fact that it owns negative capital means that these households accumulate capital at a faster rate than in the previous model. The growth rate of Q2 increases as well, being in the extended model closer to the economy-wide rate than in the original model (0.13 p.p. versus 0.05 p.p.).

Moreover, the increased labor supply of Q1 on impact does not offset the sharp decrease in the labor supply of Q3-Q5, resulting in a small but negative change in the average effort. While for Q1-Q4 the labor supply does not change significantly throughout the transition after the initial response, the highest quintile enjoys more leisure over time as it becomes wealthier. Likewise, the long-run effect on aggregate labor supply is a small decrease on aggregate employment, a result that is consistent with empirical evidence.

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[120] One of the direct implications of these differences in the calibrated IES is that the highest quintile, although more patient than the average, becomes relatively less willing to substitute future for present consumption, which results in a larger increase of consumption by this group in the short run.

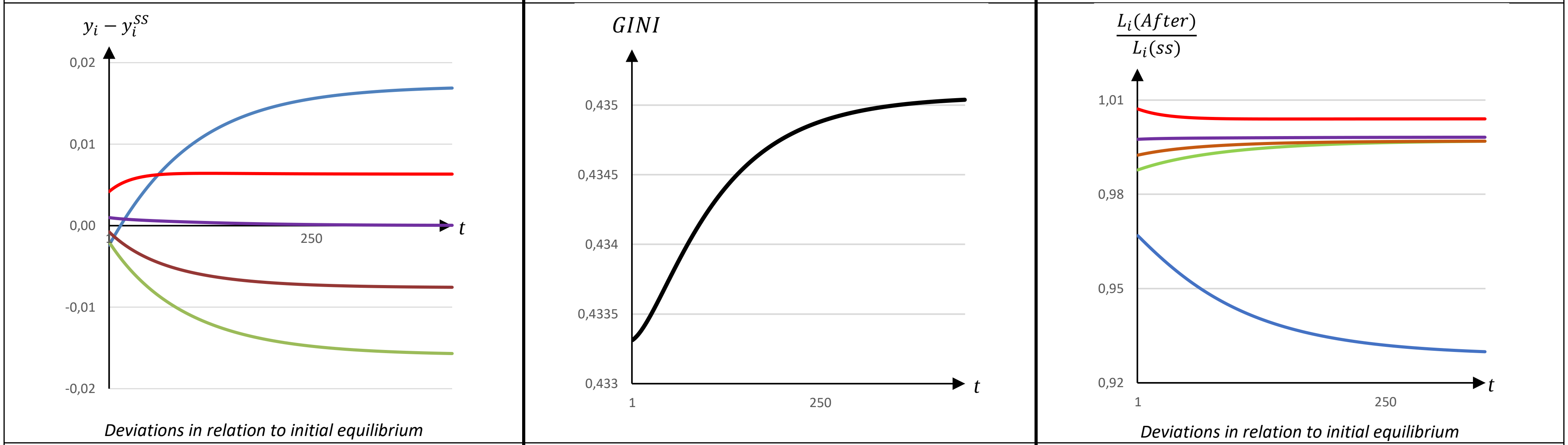
Table 3.9 – Initial Steady-State Equilibrium of the extended model

Aggregate Growth Rate of Capital ($\tilde{\psi}$)	2.46	
Labor Supply		
Q1: First quintile $(1-l_1)$	0.442	
Q2: Second quintile $(1-l_2)$	0.464	
Q3: Third quintile $(1-l_3)$	0.453	
Q4: Fourth quintile $(1-l_4)$	0.380	
Q5: Highest quintile $(1-l_5)$	0.113	
Average	0.370	
Individual Tax Rate		
Q1: τ_1	1.15%	
Q2: τ_2	9.5%	
Q3: τ_3	13.4%	
Q4: τ_4	16.8%	
Q5: τ_5	21.6%	
Marginal Tax Rate		
Q1: ${\tau_1}^m$	12.3%	
Q2: ${\tau_2}^m$	18.2%	
Q3: ${\tau_3}^m$	21.0%	
Q4: ${\tau_4}^m$	23.4%	
Q5: ${\tau_5}^m$	26.8%	
Capital Shares	k_i	$[(k_i/N)\cdot 100]$
Q1 (k_1)	-0.21	-4.1%
Q2 (k_2)	0.11	2.3%
Q3 (k_3)	0.49	9.8%
Q4 (k_4)	1.18	23.5%
Q5 (k_5)	3.43	68.5%
Income Shares	y_i	$[(y_i/N)\cdot 100]$
Q1 (y_1)	0.19	3.7%
Q2 (y_2)	0.43	8.7%
Q3 (y_3)	0.70	13.9%
Q4 (y_4)	1.13	22.7%
Q5 (y_5)	2.55	51.0%

Table 3.10 – Impact and Long Run Effects of TCJA 2017 in the extended model

	Impact	**After 10 periods**	**Long-run**
Δ[Growth rate, ψ]			
Aggregate	0.157	0.157	0.158
Q1	0.076	0.097	0.158
Q2	0.134	0.140	0.158
Q3	0.123	0.128	0.158
Q4	0.135	0.137	0.158
Q5	0.165	0.165	0.158
Δ[Labor Allocation, L]			
Aggregate	-0.0020	-0.0020	-0.0019
Q1	0.0032	0.0028	0.0018
Q2	-0.0011	-0.0011	-0.0008
Q3	-0.0034	-0.0032	-0.0014
Q4	-0.0046	-0.0043	-0.0011
Q5	-0.0037	-0.0041	-0.0080
Average Tax Rate, τ			
Aggregate	15.56%	15.56%	15.57%
Q1	-3.10%	-3.05%	-2.95%
Q2	6.51%	6.50%	6.48%
Q3	10.95%	10.94%	10.86%
Q4	14.83%	14.82%	14.74%
Q5	20.07%	20.07%	20.11%
Marginal Tax Rate, τ^m			
Aggregate	19.68%	19.68%	19.68%
Q1	10.22%	10.25%	10.32%
Q2	16.63%	16.63%	16.62%
Q3	19.60%	19.59%	19.54%
Q4	22.19%	22.18%	22.13%
Q5	25.69%	25.69%	25.72%
Δ[Income GINI]	-0.129	-0.124	0.044
Δ[Wealth GINI]	0.000	0.003	0.261
Δ[Income Share, y_i]			
Q1	0.0008	0.0010	0.0013
Q2	0.0002	0.0002	0.0000
Q3	-0.0002	-0.0003	-0.0015
Q4	-0.0004	-0.0007	-0.0032
Q5	-0.0005	-0.0002	0.0034
Δ[After-tax Inc. Share, ${y_i}^a$]			
Q1	0.0018	0.0020	0.0023
Q2	0.0010	0.0010	0.0008
Q3	0.0004	0.0002	-0.0009
Q4	-0.0005	-0.0007	-0.0030
Q5	-0.0027	-0.0025	0.0008
Δ[Wealth Share, k_i]			
Q1	0.000	0.0003	0.0009
Q2	0.000	0.0000	-0.0003
Q3	0.000	-0.0003	-0.0023
Q4	0.000	-0.0004	-0.0046
Q5	0.000	0.0005	0.0063

Figure 3.5 – Dynamic Effects of the TCJA 2017 in the extended model



(a) Effects on Income Distribution

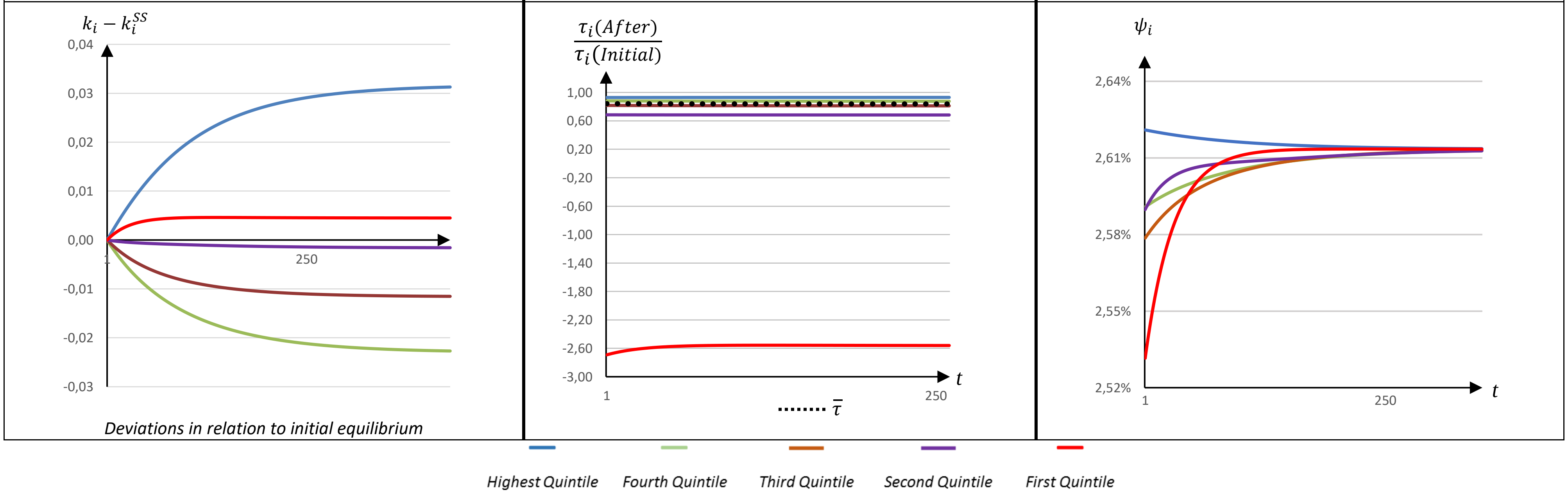
(b) Effects on Income GINI Coefficient

(c) Effects on Labor Supply

(d) Effects on Capital Distribution

(e) Effects on Average Progressive Tax

(f) Individual Growth Rates of Capital



The simulated effects of the TCJA 2017 in the extended model produces the same long-run effect on economic growth, while affecting more mildly the distribution of income than in the original model. The smaller increase in capital accumulation by the richest individuals coupled with the increase by the poorest quintiles yield modest long-run distributional effects in the extended model, without changing significantly the *status quo*. This milder distributional effect of the extended model, relative to the original one, is summarized by the Gini coefficient of income – that increases by 0.04 p.p., rather than 0.29 p.p.– and the Gini coefficient of capital – that increases by 0.26 p.p., rather than 0.65 p.p. Indeed, this is a direct implication of the assumption that heterogeneity arises from different impatience rates across individuals as well as from how they adjust their consumption and saving rate to the changes in the after-tax return on capital.

3.6 Concluding Remarks

This chapter examined the effects on impact, the transition, and the steady state, of a tax cut with the broad characteristics of the TCJA 2017 (Tax Cut and Jobs Act) with special reference to inequality and growth. The analysis uses an endogenous growth model with heterogeneous households characterized by different intertemporal elasticity of substitution, and an income distribution disaggregated by quintiles. It also uses a parametric the tax schedule that generalizes the one designed by Guo and Lansing (1998), and is more accurate in reproducing the empirically observed US tax code. The latter is in itself an important contribution to the literature.

The solution of the model yields a unique non-degenerate distribution of both income and wealth, where the households that have relatively larger willingness to substitute future consumption for present consumption turn out to accumulate more wealth. It allows a more precise assessment of the tradeoff between inequality reduction and economic growth than that obtained with other models that use a more conventional specification of the heterogeneity. In spite of the high level of aggregation and simplifications of the model, the evaluation of the effects on growth and distribution of the changes in the tax schedule parameters simulated here are realistic, because it considers the deviations of the relevant variables from the benchmark, which are robust to the departures of the model from the real economy.

The simulations consider a tax cut coupled with changes in the progressiveness of the tax, financed by a reduction of public consumption, and indicate that the dynamic responses of income, wealth, effort and savings differ substantially across the quintiles. In the presence of progressivity, a change in the value of the parameter that drives the scale of the tax schedule implies asymmetric reductions in the tax rates that benefit the poorest quintiles proportionately more than the richest quintile. The aggregate results of the fiscal policy considered here are an increase economic activity coupled with an increase in inequality. The former is of approximately 0.161 percentage points (p.p.) in the short run, which is sustained during the transition, and increases to 0.164 p.p. in the long run. The latter corresponds to an increase of about 0.7% in the GINI coefficient of income. Hence, the economy displays a positive long-run growth-inequality tradeoff.

Carneiro et al. (2022) highlight the sensitivity of the growth-inequality tradeoff to the progressivity of the tax structure but show that with a judicious choice of the fiscal parameters it is possible to design a tax cut that increases the growth rate and simultaneously reduces inequality. In light of the results obtained by the simulations discussed here, the TCJA 2017, if not able to avoid the long-run tradeoff between growth and income inequality, at least came very close to it. Indeed, the tax cut increases economic growth and is effective in reducing inequality in the short run, although in the long run it slightly deepens inequality as a result of the relative impoverishment of the middle quintiles.

The contrasting effects of that policy across the quintiles of the income distribution is due not only to asymmetric tax benefits, but also to the role that differences in EIS play in determining the capital accumulation responses of each household. In the long run the middle-income quintiles reduce their relative share of capital and income during the transition, the effect on income share of the poorest quintile is negligible, and the highest quintile ends up with a higher relative share of capital and income. The tax cut also produces to a small overall decrease in the long-run labor supply, because it induces an increase of the leisure of the richest income quintiles, especially the highest one, which more than offsets the decrease of the poorest quintile.

To assess to what extent the proposed modelling of household heterogeneity affects the qualitative results, an extended version of the model where there are also differences of the RTP (Rate of Time Preference), which is the more frequently encountered specification of household heterogeneity, is also considered. The calibration of extended model is such that the benchmark equilibrium is virtually the equal to the original model, and the same fiscal policy is simulated. The results show a similar positive effect to the average economy-wide growth rate, and more subtle distributional effects, since the income GINI rises by only 0.1%. This implies that differences in the RTP play an important role in the dynamics of the income distribution, although it is less important than differences with respect to EIS.

In conclusion, the formulation of household heterogeneity based on differences of the EIS proposed here displays several theoretical and empirical advantages with respect to the formulation usually adopted in macrodynamic models, based on differences in the discount rate, and avoids the lack of robust empirical evidence to support the latter. Further, there is significant empirical support for the fact that it varies broadly between household quintiles for the USA economy. Since it underlies both versions of the model, one can infer that they lead to satisfactory and credible dynamic responses when simulating an actual fiscal policy in a counter factual exercise.

Finally, the two approaches to heterogeneity, when combined in an extended version of the model, assess the TCJA 2017 effects in a broader perspective. Moreover, it allows testing the persistence of the growth-inequality tradeoff when different sources of agent heterogeneity are admitted. Nevertheless, the absence of a consensus that poor households have higher discount rates than rich ones implies greater confidence in the results of the model in which heterogeneity arises only from IES, and therefore that the distributional effects triggered by TCJA 2017 are more significant.

FINAL CONSIDERATIONS

This thesis contains three essays that discuss the effects of fiscal policies in economies with heterogeneous agents, which respond differently and enjoy asymmetric gains and losses from fiscal reforms, irrespective of the source of their heterogeneity. Such unbalanced outcomes represent an important economic issue that policymakers need to take into consideration when designing those policies, because they may have a significant effect on the macroeconomic outcomes, and have important social implications. Each essay offers, in addition to significant methodological contributions to the literature, quantitative assessments that provide keen insights with respect to Brazilian and US current fiscal and economic policy issues, with a broader and novel attention to its distinct effects for households in different income classes. The findings have very significant value for assessing and tailoring these policies for broader acceptability across the economic agents.

The first essay points out that the choice of fiscal strategy is crucial in determining the effects on economic growth and household welfare of public debt stabilization policies under consideration in Brazil. The quantitative analysis focuses on that particular country, but the model, approach, and possibly several of the conclusions, have much broader applicability to other highly indebted countries. It adopts the conventional neoclassical growth framework, and considers the heterogeneity of households with respect to the access to the financial system, and the ability to smooth consumption over time. The empirical application shows that the changes in the tax mix can stabilize the public debt while stimulating economic activity and increasing aggregate welfare in the long run, but the effectiveness of different policy instruments mixes varies broadly. The main reason is that they produce very different effects on the consumption decisions of the two different household types considered there, and different fiscal policies may result in very asymmetrical and possibly unfair distribution of its gains and costs. It also discusses and ranks the fiscal instruments when the government can only choose a single instrument to stabilize the public debt, but can vary its level over time.

The second and third essays adopt the more recent endogenous growth framework, and address the growth-inequality tradeoffs of policies that reduce or eliminate the progressivity of the tax system. They characterize the heterogeneity of households by differences in their elasticity of intertemporal substitution (EIS), innovating and extending the literature in that respect. The numeric model calibrates the EIS of the several quintiles of the income distribution to match the US income distribution, a disaggregation that allows the finer characterization of the tax schedule in terms of the income of the household types and sharper representation of the income and wealth distribution – and how the simulated policies affect it. Both models consider a parametric specification of the income tax expression based on the one proposed by Guo and Lansing (1998), but tailored to the objectives of each essay, as described below.

The second essay considers different schedules for the capital and labor income taxes in the US economy, as does Chen (2020), and considers two hypothetical scenarios for redistributive income tax policies. The first scenario considers the elimination of the progressivity of the labor income tax, without changing the progressivity of the tax on capital income, and finds that it does not lead significant redistributive effects, but increases the economic growth rate. The second scenario also considers an increase in the progressivity of the capital income tax, in addition to the policy of the first scenario, and finds that it reduces inequality faster and further, but at the cost of a significant reduction of economic growth.

The third essay does not distinguish the functional disaggregation of the income tax, but proposes an original generalization of the parametric specification of Guo and Lansing (1998), that yields a better empirical fit to the observed tax schedule in the US. This is an important methodological extension, applicable for other countries as well, especially those that are considering steep increases in the marginal taxes of high-income households, because it includes a parameter that tailors the asymptotic behavior of the tax schedule. The counterfactual exercises to evaluate the effects of the Tax Cut and Jobs Act (TCJA) of 2017 in the US is done with two numeric calibrated versions of the model. The first considers the original model with household heterogeneity only with respect to their EIS, while the second additionally considers household heterogeneity with respect to the rate of time preference (RTP). The latter is included mostly because the variations in the RTP is the manner in which household heterogeneity is most often treated in the literature, in spite of scant empirical support it. The comparison of the results of the two versions of the model shows the relevance of the characterization of heterogeneity through EIS, proposed in these two essays of the thesis. Their results are relevant to indicate the short and long run effects of the TCJA 2017, in spite of the idealized context of model and its calibrated numerical version, especially because they are departures from the benchmark trajectory of the economy.

The original model indicates that the TCJA 2017 increased the economic growth rate by 0.16 percentage points (p.p.) in the long run, and produced a increase of income inequality represented by a rise of about 0.3 p.p. in the GINI coefficient of income. The extended model, which also considers the differences in the RTP in the characterization of household heterogeneity, shows virtually the same increase of the economic growth rate (0.16 p.p.) and a much smaller increase of the GINI coefficient (0.04 p.p.). Hence, we can conclude that the TCJA 2017 induces an increase economic activity coupled with an mild increase in inequality in the long-run. Both versions of the model show that the distributive effect of a fiscal reform that essentially shifts the income tax schedule downward is due to the asymmetric fiscal benefits that favor the poorest quintiles proportionately more than the top income quintile, and the specification of the model that in some respects depends on the relative income and wealth. Nevertheless, the response to the tax cut varies widely across households due to differences in saving behaviors.

The results in the last two essays enlarge the body of quantitative analysis regarding the effects of progressive tax structures on the growth rate, labor supply, and income inequality. Furthermore, these two essays shed a light on the fiscal reforms debates by showing how different tax strategies can lead to undesirable and unexpected consequences regarding the growth-distribution tradeoffs and how sensitive such tradeoffs are to policy changes in a context of progressive taxation, endorsing and extending the results reported by Carneiro et al. (2022).

Overall, these three essays provide a roadmap for future research and address other questions still pending in this strand of literature as, for example, the following ones. First, accounting for heterogeneity of agents in the model is of crucial importance, and incorporating other sources of it may have significant economic implications. Second, the design of other aspects of fiscal reforms merits further investigation, such as the length of the debt stabilization program, and the attunement of fiscal parameters reforms, since the use of optimally set parameters may moderate, or even eliminate, the growth-inequality tradeoff and the effects of a more aggressive progressive tax reform. Finally, it may be very illuminating to perform empirical analysis on observed data to complement, and verify the results of the calibrated models used here.

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