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FISCAL POLICY, DISTORTIONARY TAXATION, AND BUSINESS CYCLES: THE ROLE OF HETEROGENEOUS AGENTS

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Abstract

This thesis presents a New Keynesian dynamic stochastic general equilibrium (DSGE) model introducing heterogeneous agents and distortionary taxation, and calibrates it for the Mexican economy. We consider Ricardian households, who access the financial market, and non-Ricardian households, who do not and consume only their disposable income. A high share of non-Ricardian households generates an upward-sloping IS curve, which the calibration suggests to be empirically realistic for Mexico. A quantitative analysis is undertaken to investigate the determinacy properties of the model before next considering how the shock transmission mechanism differs under income and consumption taxation. For a low share of non-Ricardian households, determinacy regions are broader under the consumption tax system and monetary policy can follow the Taylor principle, while for a high share, under the income tax system, monetary policy can follow either the Taylor principle or the 'inverted Taylor principle'. The impulse response analysis shows that under the income tax system shocks to productivity, monetary policy, and government spending have different correlations to output, depending on the shape of the IS curve, while under the consumption tax system these correlations always have the same direction. Furthermore, under the consumption tax system, fiscal policy is ineffective, as this tax counteracts the aggregate demand effects of government spending shocks.

Contents

Chapter 1

Introduction

In many developing countries a large part of the population does not have access to financial markets. According to the Global Findex database, in the OECD countries 89.74% of the population has a financial account, while in Latin American and Caribbean countries financial account ownership falls to 52.14% (see Table 1.1).[1] Consequently, an important share of the population in emerging economies cannot allocate resources intertemporally, which has important implications on aggregate consumption and savings. Therefore, it seems necessary to take into account asset market participation.

For the case of Mexico, Table 1.1 shows that it is the OECD member with the lowest ownership of financial accounts and is also among the Latin American and Caribbean countries with the lowest levels.[2] Note that, in general, the share of population with access to financial accounts is far higher in the OECD countries than in the Latin American and Caribbean countries. Therefore, considering low asset market participation is especially important for developing countries.

Most macro models ignore this important feature, present in many economies. It has been generally assumed that households have complete access to financial markets, which allows them to hold different assets in order to smooth consumption over time. The low asset market participation in developing countries implies that most of their population cannot follow this behaviour. Instead, these households would act as 'rule-of-thumb' consumers, i.e., consuming

[1] The definition of 'financial account' from the Global Findex report considers accounts from banks or other financial institutions, as well as mobile money services.The average for the OECD was calculated with 34 members, not including Iceland, Switzerland and Korea; while the Latin America and the Caribbean average includes 18 countries: Trinidad and Tobago, Chile, Brazil, Costa Rica, Uruguay, Dominican Republic, Bolivia, Ecuador, Argentina, Paraguay, Panama, Colombia, Honduras, Guatemala, Peru, Mexico, Nicaragua and El Salvador.

[2] The estimation for Mexico is consistent with the report from the National Survey on Financial Inclusion 2018 (ENIF, Encuesta Nacional de Inclusión Financiera), which states that only 36% of the Mexican population has a savings account, while 31% has access to formal credit.

only their current disposable income and not being able to save for future consumption. Because these agents do not have access to financial markets, Ricardian Equivalence fails (as they are credit constrained). That is why these agents have been called 'non-Ricardian' households by the literature.[3]

Table 1.1. Financial account ownership as a percentage of population, 2017

Country	% of population	Country	% of population
OECD			
Denmark	99.92	Italy	93.79
Canada	99.73	Spain	93.76
Germany	99.14	United States	93.12
Japan	98.24	Poland	86.73
United Kingdom	96.37	Greece	85.47
Ireland	95.34	Hungary	74.94
France	94.00	Turkey	68.59
		Average	89.74
Latin America and the Caribbean			
Trinidad and Tobago	80.78	Colombia	45.76
Chile	74.35	Honduras	45.34
Brazil	70.04	Guatemala	44.11
Uruguay	63.87	Peru	42.60
Bolivia	54.41	Mexico	36.93
Ecuador	51.25	Nicaragua	30.86
Argentina	48.71	El Salvador	30.35
		Average	52.14

Source: Gobal Findex database, World Bank.

Following a similar reasoning, Mankiw (2000) pointed out that traditional models were deficient in explaining certain aspects of reality, especially when it comes to fiscal policy, and urged to consider heterogeneous agents in the analysis. Introducing agents with financial constraints in traditional models, along with fiscal policy, may account for the positive relationship between government expenditure and private consumption observed in empirical research (Blanchard, Perotti 2003). Without access to financial markets, even if households expected higher taxes after a rise in government spending, they could not reduce their

[3]See Galí, López-Salido and Vallés (2003a) and Bilbiie and Straub (2003).

current consumption to face the future higher tax burden. This implies that by introducing heterogeneous agents in the analysis Ricardian Equivalence might not hold.

In line with the above, asset market participation becomes even more important when considering fiscal policy. According to data from the Ministry of Finance and Public Credit (SHCP, Secretaría de Hacienda y Crédito Público), income tax collection represented 22% of the federal budget revenue in 2000 and 32.5% in 2018, while VAT collection represented 16.1% in 2000 and 18% in 2018. By this, the contribution of distortionary taxation on income and consumption has been increasing over the years, representing more than 50% of the federal budget revenue in Mexico. Also, it is worth noting that the contribution of the income tax increased more than 10 percentage points during the 2000-2018 period, while for the consumption tax only increased less than two percentage points. This shows the predominance of the income tax system in Mexico.

Under a similar analysis, according to data from the OECD, income tax collection as a percentage of GDP in Mexico rose from 4.13% in 2000 to 7.17% in 2017, while VAT collection only rose from 2.83% to 3.72%. By contrast, other countries in Latin America have increased their revenues relying on VAT collection. Income tax collection in Latin America and the Caribbean rose from 4.37% to 6.04%, while VAT collection rose from 3.99% to 5.90%, during the same period. This shows a more balanced tax structure in Latin America, considering income and consumption taxes, with a slight recent shift towards the consumption tax system.

Furthermore, Mexico is the last country among the OECD in tax revenue. Tax revenue as a percentage of GDP for this country (16.1%) is less than half the OECD average (33.82%), and is even below the Latin American and Caribbean average (22.8%).[4] Therefore, considering the distortionary taxation structure in Mexico and its low tax collection, aiming to increase tax revenues would likely conduct to increasing the income and consumption tax rates, which might have determinant implications in an economy with low asset market participation. Moreover, it is pertinent to ask which of the two tax systems is the most appropriate for the Mexican economy.[5]

Given these aspects of the Mexican economy, we simulate a New-Keynesian dynamic stochastic general equilibrium (DSGE) model introducing heterogeneous agents and

[4]The OECD average includes the 37 members, while the Latin America and the Caribbean average includes 24 countries: Cuba, Brazil, Barbados, Uruguay, Argentina, Belize, Jamaica, Guyana, Costa Rica, Bolivia, Nicaragua, Honduras, Trinidad and Tobago, El Salvador, Chile, Ecuador, Colombia, Bahamas, Mexico, Peru, Panama, Dominican Republic, Paraguay and Guatemala.

[5]A large literature that has studied the implications of both tax systems, e.g., Motta and Rossi (2013) and Giannitsarou (2007) argue that consumption taxes are preferable to income taxes for welfare and stability reasons, respectively. However, these studies are based on homogeneous Ricardian agents models.

distortionary taxation, and calibrate it for Mexico. The aim is to analyze the effects of heterogeneous agents on business cycles, in a framework of distortionary income and consumption taxation. First, we examine the effect of heterogeneous agents, distortionary taxation, and government debt, on determining the shape of the IS curve. As showed by Bilbiie (2008), considering limited asset market participation (LAMP) can account for an 'Inverted Aggregate Demand Logic' (IADL), which arises with a high share of non-Ricardian households and is characterized by an upward-sloping IS curve. By contrast, with a low share of non-Ricardian households, the economy follows the 'Standard Aggregate Demand Logic' (SADL) with a downward-sloping IS curve. This allows us to explore how different features of fiscal policy affect monetary policy in a LAMP framework through a determinacy analysis, which is important for analyzing the conditions that allow for economic stability. Then, we examine the effect of heterogeneous agents and distortionary taxation after shocks to productivity, the nominal interest rate and government spending, as the shape of the IS curve and the different tax systems imply different transmission mechanisms for each shock. To compare the impulse responses after the shocks under the SADL and the IADL, we consider two sets of parameters, the IADL case is represented by the Mexican economy, while the IADL is achieved by modifying the share of non-Ricardian households and the inflation response coefficient for determinacy reasons.

The baseline model consists on a LAMP model following Bilbiie (2008), which introduces the heterogeneity of the agents by considering a fraction of non-Ricardian households with zero asset holdings that consume their current disposable income, while the rest are Ricardian households that own the financial assets and can smooth consumption over time. As is standard in literature, a representative, competitive firm produces a final good using intermediate goods as inputs, which are produced by monopolistically competitive firms, that set prices following Calvo (1983), using only labor.[6] Monetary policy is set following a forward-looking Taylor rule, while fiscal policy follows a balanced budget rule, with government spending being financed by distortionary taxes on income and consumption in a similar way to McKnight (2017).[7] The choice for the monetary policy rule is based on the fact that since 2001 Banco de México follows an inflation targeting regime for its monetary policy (Banxico 2017), while the balanced budget rule is supported by the Federal Law on Budget and Treasury Responsibility

[6] One of the main aspects in which New-Keynesian models depart from the Real Business Cycle (RBC) theory, developed after the seminal papers of Kydland and Prescott (1982) and Prescott (1986), is the introduction of monopolistic competition and nominal rigidities. For a discussion of the main features of production in New-Keynesian DSGE models, see Goodfriend and King (2007) and Galí (2008).

[7] Woodford (2003a, 2003b) discusses the importance of inflation-targeting monetary policy rules.

(LFPRH, Ley Federal de Presupuesto y Responsabilidad Hacendaria).

Introducing heterogeneous agents in a traditional model has important effects on local dynamics. As Bilbiie (2008) showed, the shape of the IS curve depends on the level of asset market participation and the labor supply elasticity. Extending this analysis, we explore the effects of distortionary taxation and government debt on modifying the shape of the IS curve. Afterwards, we conduct a determinacy analysis similar to Galí, López-Salido and Vallés (2004a), who examine the combinations of the values of the asset market participation and the inflation response coefficient that allows for equilibrium determinacy. However, as we incorporate fiscal policy, we evaluate the effect of increasing the tax rates and government debt on the determinacy regions, and hence analyzing the interaction between fiscal and monetary policy.[8]

These features allow the model to account for different transmission mechanisms after shocks to productivity, monetary policy, and government spending, depending on asset market participation, and more specifically, on the shape of the IS curve. We compare and analyze the results of the impulse response functions generated under different levels of asset market participation. By this analysis we are able to compare the income and consumption tax system, which generates important policy recommendations for the Mexican economy.

Similar to Bilbiie (2008), we find that the elasticity of labor supply is crucial for the threshold of asset market participation that determines the shape of the IS curve. However, fiscal policy is also shown to affect the slope of the IS curve. By this, steady state rates from distortionary taxes have an effect on the shape of the IS curve. Comparing the income tax system with the consumption tax system, we find that taxing income has a bigger impact on the shape of the IS curve than consumption taxation. This implies that the income tax reduces the possibility of falling into the IADL. On the other hand, government debt seems to have a minor effect on the shape of the IS curve under both tax systems.

The determinacy analysis suggests that, under a strict inflation-targeting forward-looking monetary policy rule, the determinacy regions under the income tax system are considerably smaller than under the consumption tax system, when the economy follows the SADL. Furthermore, increasing government debt reduces the determinacy regions under the income tax system and does not have a visible effect under the consumption tax system. Hence, under the SADL and the income tax system, monetary policy has a very small scope of

[8] The importance of equilibrium determinacy has been covered extensively by literature. Considering a New Keynesian framework with only monetary policy, see Woodford (2003b), Duffy and Xiao (2011), and McKnight and Mihailov (2015). For the determinacy implications of fiscal policy, see Schmitt-Grohé and Uribe (1997), Kurozomi (2010), and McKnight (2017).

action, while under the consumption tax system, the Taylor principle can be followed. This results are in line with McKnight (2017), who showed that the Taylor principle struggles to induce determinacy under income taxation, whereas determinacy is easily achieved under consumption taxation. However, the income tax seems to reduce the range for which the economy follows the IADL, where monetary policy follow the 'Inverted Taylor Principle', i.e., a passive monetary policy (Bilbiie, 2008). Moreover, as the steady state income tax rate increases, so does the upper bound of the inflation response coefficient that allows for determinacy, which implies that monetary policy can follow the Taylor principle too. By these results, the consumption tax seems preferable for the SADL, while for the IADL, the income tax seems preferable. Consequently, the monetary authority must consider these features of fiscal policy when designing a monetary policy rule, otherwise, self-fulfilling might arise, generating instability in the economy.

The impulse response analysis shows how, depending shape of the IS curve and the tax system, different transmission mechanisms can arise. Considering low and high levels of asset market participation, we achieve different transmission mechanisms under the income tax system, which imply opposite correlations of output and the shocks under the SADL and the IADL. Also, the model can account for 'non-Keynesian effects' of government spending (Bilbiie and Straub, 2003), as a positive government spending shock has a negative effect on output under the IADL, which is related to the expansionary effects of fiscal consolidation. By contrast, under the consumption tax system, the correlation between output and the shocks goes in the same direction under the SADL and the IADL. An important result under the income tax system is that this tax makes fiscal policy to be ineffective, as the consumption tax counteracts the aggregate demand effect of government spending. Additionally, the consumption tax is shown to have important properties as an automatic stabilizer, as most of the variables practically return to their steady state levels one period after productivity and monetary shocks.

This thesis follows a recent tradition of LAMP models, inspired by the empirical research of Campbell and Mankiw (1989), who showed that income and consumption data are best viewed as generated by forward-looking and 'rule-of-thumb' consumers, instead of the standard representative agent.[9]

Galí, López-Salido and Vallés (2004a) develop a traditional New Keynesian DSGE model that introduces heterogeneous agents, Ricardian and non-Ricardian (or 'rule-of-thumb') households, to analyze the designing of monetary policy rule under this

[9]They found that, for the United States, the fraction of 'rule-of-thumb' consumers was around 50%, while in a later research (Campbell and Mankiw, 1991) a cross-country analysis showed proportions from 20% in Canada to nearly 100% in France.

framework. However, that model is different from the one presented here as it does not include government.[10] This paper also analyzes the effect of heterogeneous agents on equilibrium determinacy under a current-looking monetary policy rule and for different levels of the baseline parameters. The approach followed here is very different from theirs in the way that we are interested in the interaction of fiscal and monetary policy under an heterogeneous households framework, while considering a forward-looking monetary policy rule. Our analysis is more similar to the one carried out by McKnight (2017), who shows how for different distortionary tax systems the indeterminacy problem arises depending on the the steady state features of fiscal policy under a representative agent framework.

Exploring the effects of heterogeneous agents and the role of fiscal policy, Galí, López-Salido and Vallés (2004b) model a fiscal authority where government spending is financed by lump-sum taxes and following a fiscal policy rule. In a similar framework, Bilbiie and Straub (2004) study the effects and transmission mechanisms of fiscal policy in a LAMP model, considering lump-sum and distortionary income taxation. Both papers analyze the conditions under which the heterogeneous agents break with Ricardian equivalence. The latter finds that to achieve a positive relationship between government spending and private consumption, it is necessary that: the spending shock is low enough and/or the monetary policy response to inflation is passive and/or price stickiness is high. Our analysis goes further than these studies by considering the consumption taxation case, which allows us to compare different distortionary taxation systems. Both papers use a fiscal policy rule that allows government spending to be financed by lump-sum or income taxation, and debt. However, a balanced budget rule is a better option for this case, considering the Mexican legislation. Moreover, for the impulse response analyses, these papers focus on government spending shocks. We extend this analysis by also considering productivity and monetary shocks, in order to have a deeper understanding of the effects of heterogeneous agents on business cycles. This also allows us to compare the different distortionary tax systems under different scenarios.

In a later research, Bilbiie (2008) studies the implications of the LAMP model in terms of equilibrium determinacy and optimal monetary policy. As mentioned before, under moderate degrees of asset market participation, i.e., a low share of non-Ricardian agents, aggregate demands follows the SADL, with a negative relationship between output and the real interest rate, and non-Ricardian households generate strengthen macrodynamics. He finds that under this shape of the IS curve, monetary policy can act according to the

[10] In recent years, heterogeneous agents New Keynesian (HANK) models have been developed as an alternative to LAMP models. HANK models introduce stochastic processes to account for the heterogeneity of the agents over time. See Kaplan, Moll, and Violante (2018).

Taylor principle, responding to inflation with more than proportionate adjustments on the interest rate. On the other hand, with a low asset market participation or low levels of labor supply elasticity, the economy follows the IADL, characterized by an upward-sloping IS curve. Furthermore, to achieve a unique rational expectations equilibrium, the central bank needs to adopt a passive policy rule, which he calls the 'Inverted Taylor Principle'. Therefore, the central bank adjusts the nominal interest rate less than proportionally to inflation, implying that the real interest rate falls when inflation rises. We show that both, the Taylor and the inverted Taylor principle do not necessarily guarantee equilibrium determinacy when considering distortionary taxation and government debt.

This thesis proceeds as follows: in Chapter 2 we outline the model with heterogeneous agents and distortionary taxation; Chapter 3 shows the log-linearized model and calibration for the Mexican economy, including an analysis on the shape of the IS curve, focusing on the role of heterogeneous agents and fiscal policy features; in Chapter 4 we analyze equilibrium determinacy; Chapter 5 presents the impulse response analysis under the different shocks and tax systems; finally, Chapter 6 presents the conclusions of the thesis.

Chapter 2

A New Keynesian model with heterogeneous agents and distortionary taxation

The model consists of a closed economy with heterogeneous households, Ricardian and non-Ricardian, a representative final good producing firm and intermediate-goods firms, along with a fiscal authority and the central bank. Households supply labor to intermediate-goods producers and purchase a final good for consumption. Only the Ricardian households are assumed to hold government bonds and own the intermediate firms. A representative competitive firm produces a final good using intermediate goods as inputs. Intermediate-goods firms use labor to produce intermediate goods. Intermediate-goods producing firms are assumed to be monopolistically competitive. Prices for the intermediate goods are staggered and are set following Calvo (1983). Monetary policy is conducted using an interest-rate rule, while fiscal policy follows a balanced budget rule. The government finances its spending using distortionary taxes on consumption, income (including bond interest), and issuing debt. Furthermore, we consider three different exogenous shocks to productivity, monetary policy and government spending.

2.1 Households

Households are modelled by a continuum $[0, 1]$, where a $1-\lambda$ share is represented by standard 'Ricardian' households who have access to financial markets where a non-state-contingent government bond can be purchased. Consequently, $1-\lambda$ reflects the degree of asset market participation. We also assume that they are the owners of intermediate-sector firms. The rest of the households λ do not participate in the financial market, hence they cannot smooth consumption and are denoted as 'non-Ricardian' households.

2.1.1 Ricardian households

Each Ricardian household $j\epsilon[1-\lambda,\ 1]$, which are denoted with the subscript S, choose their consumption C_S, bond holdings B_S and labor supply N_S to maximize expected discounted utility:

$$\max_{C_{S,t},N_{S,t},B_{S,t}} E_t \sum_{t=0}^{\infty} \beta^t U_S(C_{S,t}, N_{S,t})$$

where the period utility function is given by:

$$U_S(C_{S,t}, N_{S,t}) = \frac{C_{S,t}^{1-\sigma}}{1-\sigma} - \omega \frac{N_{S,t}^{1+\varphi}}{1+\varphi}$$

where E_t denotes the expectation conditional on the information set at period t, $\beta \,\epsilon\, (0,1)$ is the discount factor, $\sigma > 0$ is the relative risk aversion coefficient of consumption, $\omega > 0$ indicates how the disutility of labor is valued relative to consumption utility, $\varphi > 0$ is the inverse labor supply elasticity. The maximization problem is subject to the sequence of period budget constraints:

$$B_{S,t} + (1+\tau_t^c)C_{S,t}P_t = \left[1 + (1-\tau_t^b)(R_{t-1}-1)\right] B_{S,t-1} + (1-\tau_t^l)\left(W_t N_{S,t} + P_t D_{S,t}\right) \quad (2.1)$$

The Ricardian agent carries $B_{S,t-1}$ holdings of one-period government bonds into period t, which pay the gross nominal interest rate R_{t-1}, W_t is the nominal wage from supplying labor, $D_{S,t}$ are real dividend payoffs from the ownership of the intermediate firms and P_t denotes the price level. Also, the Ricardian household pays distortionary taxes on consumption, income and bond interests, denoted by τ_t^c, τ_t^l and τ_t^b, respectively.

Solving the maximization problem we get the following first-order conditions:

$$\frac{C_{S,t}^{-\sigma}}{(1+\tau_t^c)P_t} = \beta E_t \left\{ \frac{C_{S,t+1}^{-\sigma}}{(1+\tau_{t+1}^c)P_{t+1}} \left[R_t - \tau_{t+1}^b(R_t - 1)\right] \right\} \quad (2.2)$$

$$\omega N_{S,t}^{\varphi} = \frac{(1-\tau_t^l)}{(1+\tau_t^c)} \frac{W_t}{P_t} C_{S,t}^{-\sigma} \quad (2.3)$$

Equation (2.2) is the consumption Euler equation and equation (2.3) is the labor supply equation for the Ricardian agent. We can see from the Euler equation (2.2) that under a consumption tax system, the intertemporal consumption decision of the Ricardian household is affected by the present and future consumption tax rates τ_t^c and τ_{t+1}^c; while in the case of the income tax system, intertemporal consumption is affected by the future bond-interest tax rate τ_{t+1}^b. On the other hand, the labor supply equation (2.3) shows how the income and consumption tax rates affect the response of labor supply to the real wage.

The transversality condition is given by:

$$\lim_{T\to\infty} E_t \left\{ \frac{B_{S,t+T}}{\Pi_{k=1}^{T}[1+(1-\tau_{t+k}^b)(R_{t+k-1}-1)]} \right\} = 0$$

2.1.2 Non-Ricardian households

The rest of the households, $j \epsilon [0, \lambda]$, do not participate in the financial market due to access constraints or being shortsighted, and are indexed by H. Hence, the parameter λ is the share of non-Ricardian households in the economy. The non-Ricardian agent solves the following problem in each period t:

$$\max_{C_{H,t},N_{H,t}} \frac{C_{H,t}^{1-\sigma}}{1-\sigma} - \omega \frac{N_{H,t}^{1+\varphi}}{1+\varphi}$$

subject to:

$$(1+\tau_t^c)C_{H,t}P_t = (1-\tau_t^l)W_t N_{H,t} \tag{2.4}$$

The first order condition is:

$$\omega N_{H,t}^{\varphi} = \frac{(1-\tau_t^l)}{(1+\tau_t^c)} \frac{W_t}{P_t} C_{H,t}^{-\sigma} \tag{2.5}$$

From the period budget constraint (2.4) we observe that the non-Ricardian households' consumption for each period is a function of income and consumption taxes, and labor income; while (2.5) is the labor supply of these households. Since the non-Ricardian household does not have access to the financial market, the household cannot maximize their consumption intertemporally (and hence the absence of the consumption Euler equation). Also, by the assumption that both agents have the same period utility function, the Ricardian household and the non-Ricardian household have the same optimal labor supply condition [see (2.3) and (2.5)].

2.2 Firms

The modelling of the firms follows a standard New Keynesian approach where the economy is comprised of a continuum of intermediate firms denoted $y_t(i)$, each indexed by $i \epsilon [0, 1]$. The final good Y_t is produced by a representative firm that behaves competitively aggregating the intermediate goods.

2.2.1 Final good producer

The final good Y_t is produced by a representative, competitive firm with an aggregation technology of the CES form:

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{2.6}$$

where $\varepsilon > 1$ is the constant elasticity of substitution between intermediate goods. The final good producer behaves competitively, maximizing profit each period:

$$\max_{Y_t(i)} \left[P_t Y_t - \int_0^1 P_t(i) Y_t(i) di \right]$$

where P_t is the price index of the final good Y_t, and $P_t(i)$ are the prices of intermediate goods $Y_t(i)$.

Profit maximization yields the demand for each intermediate input:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t \tag{2.7}$$

and by substituting (2.7) into nominal output:

$$P_t Y_t = \int_0^1 P_t(i) Y_t(i) di$$

we obtain the following expression for the price index:

$$P_t^{1-\varepsilon} = \int_0^1 P_t(i)^{1-\varepsilon} di \tag{2.8}$$

2.2.2 Intermediate-goods producers

The intermediate-goods producers face a technology that is linear in labor:

$$Y_t(i) = A_t N_t(i) \tag{2.9}$$

where A_t is the level of technology, common to all firms, and $\hat{a}_t \equiv lnA_t - lnA$, where A denotes the steady state level of technology, follows an exogenous AR(1) process given by:

$$\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_t^a \tag{2.10}$$

where $\rho_a \epsilon [0, 1]$ and ε_t^a is an i.i.d. shock such that $\varepsilon_t^a \sim N(0, \sigma_a^2)$.

Cost minimization implies that the firms will demand labor until the nominal marginal cost equals the nominal wage divided by the productivity level:

$$MC_t = \frac{W_t}{A_t} \tag{2.11}$$

The profit function in real terms is given by:

$$D_t(i) = \left[\frac{P_t(i)}{P_t}\right] Y_t(i) - \left(\frac{W_t}{P_t}\right) N_t(i) \tag{2.12}$$

which aggregated over all firms gives total profits:

$$D_t = Y_t - \frac{W_t}{P_t} N_t \tag{2.13}$$

or equivalently:

$$D_t = \left[1 - \left(\frac{MC_t}{P_t}\right) \Delta_t\right] Y_t$$

where Δ_t is the relative price dispersion:

$$\Delta_t = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} di \tag{2.14}$$

Intermediate-goods producing firms set prices *à la* Calvo (1983). These firms adjust their prices infrequently, θ is the probability of keeping the price constant and the fraction of firms that keep their prices unchanged. Intermediate-goods firms maximize the value of the firm choosing the price $P_t(i)$ and using the stochastic discount factor $\Lambda_{t,t+s}$ for nominal payoffs:

$$\max_{P_t(i)} E_t \left\{ \sum_{s=0}^{\infty} \theta^s \Lambda_{t,t+s} [P_t(i) Y_{t,t+s}(i) - mc_{t+s} Y_{t,t+s}(i)] \right\}$$

subject to the demand equation (2.7). The stochastic discount factor $\Lambda_{t,t+s} = \beta^s E_t \left\{ \left(\frac{C_{S,t+s}}{C_{S,t}}\right)^{-\sigma} \frac{(1+\tau_t^c)P_t}{(1+\tau_{t+s}^c)P_{t+s}} \right\}$ is derived from the Euler equation of the Ricardian household.

Hence the optimal price of firm i is set by:

$$P_t^*(i) = \frac{\varepsilon}{\varepsilon-1}\frac{E_t\left\{\sum_{s=0}^{\infty}\theta^s\Lambda_{t,t+s}P_{t+s}^{\varepsilon}Y_{t+s}MC_{t+s}\right\}}{E_t\left\{\sum_{s=0}^{\infty}\theta^s\Lambda_{t,t+s}P_{t+s}^{\varepsilon}Y_{t+s}\right\}} \tag{2.15}$$

$$= \frac{\varepsilon}{\varepsilon-1}E_t\left\{\sum_{s=0}^{\infty}q_{t,t+s}MC_{t+s}\right\} \tag{2.16}$$

The optimal price price set is a markup, $\frac{\epsilon}{\epsilon-1} > 1$, over the weighted average of current and future nominal marginal costs, where the weight is given by:

$$q_{t,t+s} = \frac{\theta^s\Lambda_{t,t+s}P_{t+s}^{\epsilon}Y_{t+s}}{E_t\left\{\sum_{s=0}^{\infty}\theta^s\Lambda_{t,t+s}P_{t+s}^{\epsilon}Y_{t+s}\right\}}$$

When prices are fully flexible, i.e. $\theta = 0$, the firm sets its price equal to a constant markup over its nominal marginal cost:

$$P_t^*(i) = \frac{\varepsilon}{\varepsilon-1}MC_t \tag{2.17}$$

Since all firms that can reset their prices in period t behave identically, $P_t^*(i) = P_t^*$.

The aggregate price index is:

$$P_t^{1-\varepsilon} = (1-\theta)(P_t^*)^{1-\varepsilon} + \theta P_{t-1}^{1-\varepsilon} \tag{2.18}$$

Therefore, we have the following expression for inflation:

$$\pi_t^{1-\varepsilon} = (1-\theta)\left(\frac{P_t^*}{P_{t-1}}\right)^{1-\varepsilon} + \theta \tag{2.19}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate in period t. The law of motion of relative price dispersion Δ_t from expression (2.13) is given by:

$$\Delta_t = \theta\pi_t^{\varepsilon}\Delta_{t-1} + (1-\theta)\left(\frac{P_t^*}{P_t}\right)^{-\varepsilon} \tag{2.20}$$

2.3 Monetary policy

For the monetary policy it is assumed that the monetary authority adjusts the nominal interest rate in response to changes in inflation π_t and output Y_t in a forward-looking manner, allowing for a monetary policy shock ξ_t:

$$R_t = RE_t\left\{\left(\frac{\pi_{t+1}}{\pi}\right)^{\mu_\pi}\left(\frac{Y_{t+1}}{Y}\right)^{\mu_Y}\right\}\xi_t \tag{2.21}$$

where $\mu_\pi \geq 0$ is the inflation response coefficient and $\mu_Y \geq 0$ is the output response coefficient, and $R = \frac{1-\beta\tau^b}{\beta(1-\tau^b)} > 1$, π and Y respectively denote the steady state nominal interest rate, inflation and output. Given that since 2001 Banco de México follows an inflation targeting regime for its monetary policy (Banxico 2017), this policy rule is valid for the Mexican economy.

The monetary policy shock is represented by $\hat{\chi}_t \equiv ln\xi_t$ and follows an exogenous AR(1) process given by:

$$\hat{\chi}_t = \rho_\chi \hat{\chi}_{t-1} + \varepsilon_t^\chi \tag{2.22}$$

where $\rho_\chi \, \epsilon \, [0,1]$ and ε_t^χ is an i.i.d. shock such that $\varepsilon_t^\chi \sim N(0, \sigma_\chi^2)$.

2.4 Fiscal policy

The fiscal authority purchases G_t of the final good, financed by the issuing of government debt B_t and tax revenues from distortionary taxes on consumption $\tau_t^c C_t$, real income $\tau_t^l Y_t$, or bond interests $\tau_t^b(R_{t-1} - 1)B_{t-1}$. The government budget constraint is given by:

$$P_t G_t = \tau_t^c P_t C_t + \tau_t^l P_t Y_t + \tau_t^b (R_{t-1} - 1) B_{t-1} + B_t - R_{t-1} B_{t-1} \tag{2.23}$$

where real income $Y_t = \frac{W_t}{P_t} N_t + D_t$.

Government spending, represented by $\hat{g}_t \equiv lnG_t - lnG$, where G is the steady state value of G_t, is susceptible to shocks, and follows an exogenous AR(1) process:

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + \varepsilon_t^g \tag{2.24}$$

where $\rho_g \, \epsilon \, [0,1]$ and ε_t^g is an i.i.d. shock such that $\varepsilon_t^g \sim N(0, \sigma_g^2)$.

The fiscal policy rule is specified by the following balanced budget rule, where the stock of real government debt is permanently fixed at its constant steady state level b:

$$b_t = \frac{B_t}{P_t} = b \tag{2.25}$$

A balanced budget rule seems plausible for modelling the Mexican economy since it is supported by the Federal Law on Budget and Treasury Responsibility (LFPRH, Ley Federal de Presupuesto y Responsabilidad Hacendaria).

2.5 Market clearing and aggregation

Labor market clearing requires that labor demand equals total labor supply:

$$N_t = \lambda N_{H,t} + (1-\lambda) N_{S,t} \tag{2.26}$$

Market clearing for final good requires:

$$Y_t = C_t + G_t \tag{2.27}$$

where:

$$C_t = \lambda C_{H,t} + (1-\lambda) C_{S,t} \tag{2.28}$$

As only the Ricardian households own the firms and hold government bonds, we define the following expressions for aggregate dividends and aggregate holdings, respectively:

$$D_t = (1-\lambda) D_{S,t} \tag{2.29}$$

$$B_t = (1-\lambda) B_{S,t} \tag{2.30}$$

Finally, aggregating the production function (2.9) across intermediate firms yields:

$$Y_t = \frac{A_t N_t}{\Delta_t} \tag{2.31}$$

2.6 Definition of equilibrium

The characterization of the equilibrium consists of a set of 16 endogenous variables and 3 exogenous variables: a sequence of prices $\{W_t, MC_t, P_t, P_t^*, \Delta_t\}$, a sequence of allocations $\{C_{S,t}, C_{H,t}, C_t, N_{S,t}, N_{H,t}, N_t, B_t, Y_t, D_t\}$, a fiscal policy $\{\tau_t^c\}$, $\{\tau_t^l\}$ or $\{\tau_t^b\}$; and a monetary policy $\{R_t\}$, along with the shocks considered $\{\hat{a}_t, \hat{g}_t, \hat{\chi}_t\}$, satisfying 16 equilibrium conditions and 3 laws of motion for the shocks: (i) the optimality conditions and the budget constraints of the agents (2.1)-(2.5), along with the transversality condition; (ii) the optimality condition of intermediate firms (2.11), the price setting conditions (2.16) and (2.18), the aggregate production function (2.31), the aggregate profits function (2.13) and a law of motion for price dispersion (2.20); (iii) the government budget constraint (2.23), the balanced budget rule (2.25) and the monetary policy rule (2.21); (iv) the labor market clearing (2.26) and aggregate consumption (2.28); and (v) the laws of motions for the shocks to productivity (2.10), nominal interest rate (2.22), and government spending (2.24).

Chapter 3

The log-linearized model and calibration

This chapter presents the steady state and the log-linearized version of the model. Using the log-linearized model, we derive the IS curve to analyze how the share of non-Ricardian agents in the economy λ has a crucial impact on the dynamics of the model. Depending on this degree of asset market participation, output can have a negative relationship with the real interest rate, as in the standard case, or a positive relationship, which implies an upward-sloping IS curve. We explore the effect of different tax systems and government debt on altering the level of the share of non-Ricardian households that allow standard dynamics. In the last section of this chapter, we present the calibration of the model for the Mexican economy, including two sets of parameters: one set that results in the 'Standard Aggregate Demand Logic' (SADL) and another set that implies the 'Inverted Aggregate Demand Logic' (IADL).

3.1 Steady state

Variables in the steady state are denoted without time indices, e.g., X for variable X_t. It is assumed that in the steady state prices are fully flexible and inflation is zero, as well as the dividends rebated over the Ricardian households, such that:

$$\pi = 1 \tag{3.1}$$

$$D = 0 \tag{3.2}$$

Combining expression (3.1) with the steady state version of the price setting condition (2.19) we get $P = P^*$.

Following Bilbiie and Straub (2004), it is assumed that both households supply the same amount of labor in the steady state, such that:

$$N_S = N_H = N \tag{3.3}$$

By considering the Euler equation of the Ricardian household (2.2) in the steady state, we derive the steady state levels of the stochastic discount factor Λ and the interest rate R:

$$\Lambda = \beta \tag{3.4}$$

$$R = \frac{1-\beta\tau^b}{\beta(1-\tau^b)} > 1 \tag{3.5}$$

From the price setting condition with fully flexible prices (2.17) we can derive the value of the real marginal cost in the steady state:

$$mc = \frac{MC}{P^*} \equiv \frac{\epsilon - 1}{\epsilon} > 1 \tag{3.6}$$

where mc is the steady state level of the real marginal cost.

As a consequence, with the wage setting condition (2.10) and assuming that in the steady state $A = 1$, it follows that:

$$w = mcA = \frac{\epsilon-1}{\epsilon}A = \frac{\epsilon-1}{\epsilon} \tag{3.7}$$

where $w \equiv \frac{W}{P}$ is the steady state level of the real wage.

For convenience, allocations are expressed as output shares. With the households and government budget constraints [(2.1), (2.4) and (2.21)], along with the labor market clearing condition (2.23) and consumption aggregation (2.25), in the steady state we derive the following output-share values:

$$s^{cs} = \frac{(1-\tau^l)}{(1+\tau^c)} + \frac{(1-\beta)}{(1+\tau^c)\beta}s^b \tag{3.8}$$

$$s^{ch} = \frac{(1-\tau^l)}{(1+\tau^c)} \tag{3.9}$$

$$s^c = \frac{(1-\tau^l)}{(1+\tau^c)} + (1-\lambda)\frac{(1-\beta)}{(1+\tau^c)\beta}s^b \tag{3.10}$$

$$s^g = \tau^c s^c + \tau^l - \frac{1-\beta}{\beta}s^b \tag{3.11}$$

where $s^{cs} \equiv \frac{C_S}{Y}$ and $s^{ch} \equiv \frac{C_H}{Y}$ are the consumption of the Ricardian and non-Ricardian agents as a share of output; $s^b \equiv \frac{b}{Y}$ is the government debt held by the Ricardian agent as a share of output; $s^c \equiv \frac{C}{Y}$ is the aggregate consumption as a share of output; and $s^g \equiv \frac{G}{Y}$ is the government spending as a share of output.

3.2 Log-linearized model

The model is log-linearized around the steady state of the previous section. Variables denoted by $\hat{X}_t$ represent log-deviations of X_t respect to its steady state value X, namely $\hat{X}_t \equiv lnX_t - lnX$. As aggregate dividends D_t have a zero steady state level by (3.2), this variable is log-linearized to represent log-deviations from the steady state output: $\hat{D}_t \equiv lnD_t - lnY$. Additionally, we consider three different shocks to technology $\hat{a}_t$, monetary policy $\hat{\chi}_t$ and government spending $\hat{g}_t$, as described in the previous chapter.

The log-linearized model is summarized in Table 3.1. The market clearing condition for final goods (2.27) is not included as it holds by Walras' law, making it redundant in the linearized model.

By combining the linearized versions of the price setting conditions (2.15) and (2.18), the New-Keynesian Phillips Curve (NKPC) is derived:

$$\hat{\pi}_t = \kappa \hat{mc}_t + \beta E_t \hat{\pi}_{t+1}$$

where $\kappa = \frac{(1-\theta)(1-\theta\beta)}{\theta} > 0$ is the real marginal cost elasticity of inflation, which affects the slope of the NKPC.

Also, combining the aggregation conditions for dividends (2.26) and bond holdings (2.27) with the Ricardian-household budget constraint (2.1), we get the following linearized version of the Ricardian-household budget constraint:

$$s^{cs}\tau^c\hat{\tau}^c_t + s^{cs}(1+\tau^c)\hat{C}_{S,t} = \frac{s^b(1-\beta\tau^b)}{\beta(1-\lambda)}\hat{R}_{t-1} - \frac{s^b(1-\beta)\tau^b}{\beta(1-\tau^b)(1-\lambda)}\hat{\tau}^b_t$$
$$-\frac{s^b}{\beta(1-\lambda)}\hat{\pi}_t + (1-\tau^l)\hat{w}_t + (1-\tau^l)\hat{N}_{S,t} - \tau^l\hat{\tau}^l_t + \frac{1-\tau^l}{1-\lambda}\hat{D}_t$$

Table 3.1. Summary of the log-linearized model

Euler equation, S	$\sigma E_t\hat{C}_{S,t+1} - \sigma\hat{C}_{S,t} + \frac{\tau^c}{1+\tau^c}E_t\hat{\tau}^c_{t+1} - \frac{\tau^c}{1+\tau^c}\hat{\tau}^c_t =$ $(1-\beta\tau^b)\hat{R}_t - \frac{(1-\beta)\tau^b}{1-\tau^b}E_t\hat{\tau}^b_{t+1} - E_t\hat{\pi}_{t+1}$
Labor supply, S	$\varphi\hat{N}_{S,t} = \hat{w}_t - \frac{\tau^l}{1-\tau^l}\hat{\tau}^l_t - \frac{\tau^c}{1+\tau^c}\hat{\tau}^c_t - \sigma\hat{C}_{S,t}$
Budget constraint, S	$s^{cs}\tau^c\hat{\tau}^c_t + s^{cs}(1+\tau^c)\hat{C}_{S,t} = \frac{s^b(1-\beta\tau^b)}{\beta(1-\lambda)}\hat{R}_{t-1} - \frac{s^b(1-\beta)\tau^b}{\beta(1-\tau^b)(1-\lambda)}\hat{\tau}^b_t$ $-\frac{s^b}{\beta(1-\lambda)}\hat{\pi}_t + (1-\tau^l)\hat{w}_t + (1-\tau^l)\hat{N}_{S,t} - \tau^l\hat{\tau}^l_t + \frac{1-\tau^l}{1-\lambda}\hat{D}_t$
Labor supply, H	$\varphi\hat{N}_{H,t} = \hat{w}_t - \frac{\tau^l}{1-\tau^l}\hat{\tau}^l_t - \frac{\tau^c}{1+\tau^c}\hat{\tau}^c_t - \sigma\hat{C}_{H,t}$
Budget constraint, H	$\frac{\tau^c}{1+\tau^c}\hat{\tau}^c_t + \hat{C}_{H,t} = \hat{w}_t + \hat{N}_{H,t} - \frac{\tau^l}{1-\tau^l}\hat{\tau}^l_t$
Real marginal cost	$\hat{mc}_t = \hat{w}_t - \hat{a}_t$
NKPC	$\hat{\pi}_t = \kappa\hat{mc}_t + \beta E_t\hat{\pi}_{t+1}$
Production function	$\hat{Y}_t = \hat{a}_t + \hat{N}_t$
Aggregate dividends	$\hat{D}_t = \hat{Y}_t - \hat{w}_t - \hat{N}_t$
Monetary policy rule	$\hat{R}_t = \mu_\pi E_t\hat{\pi}_{t+1} + \mu_Y E_t\hat{Y}_{t+1} + \chi_t$
Government budget constraint	$s^g\hat{g}_t = s^c\tau^c\hat{\tau}^c_t + s^c\tau^c\hat{C}_t + \tau^l\hat{\tau}^l_t + \tau^l\hat{Y}_t$ $+\frac{\tau^b(1-\beta)s^b}{(1-\tau^b)\beta}\hat{\tau}^b_t - \frac{(1-\beta\tau^b)s^b}{\beta}\hat{R}_{t-1} + \frac{s^b}{\beta}\hat{\pi}_t$
Balanced budget rule	$\hat{b}_t = 0$
Labor market clearing	$\hat{N}_t = \lambda\hat{N}_{H,t} + (1-\lambda)\hat{N}_{S,t}$
Aggregate consumption	$s^c\hat{C}_t = \lambda s^{ch}\hat{C}_{H,t} + (1-\lambda)s^{cs}\hat{C}_{S,t}$

By combining the linearized version of the labor supply and the budget constraint of the non-Ricardian household we get the following expression:

$$\hat{N}_{H,t} = \frac{1-\sigma}{1+\varphi}\hat{C}_{H,t} \tag{3.12}$$

Note that the relationship between consumption and employment of the non-Ricardian household depends on whether the risk aversion coefficient is $\sigma < 1$, in which case non-Ricardian employment is positively correlated with non-Ricardian consumption, $\sigma = 1$, where the non-Ricardian employment never deviates from its steady state value and it does not correlate with non-Ricardian consumption, or $\sigma > 1$, where the non-Ricardian employment is negatively correlated with non-Ricardian consumption.

Substituting (3.12) back into the non-Ricardian household labor supply and solving for $\hat{C}_{H,t}$, we get:

$$\hat{C}_{H,t} = \frac{1+\varphi}{\sigma+\varphi}\left(\hat{w}_t - \frac{\tau^l}{1-\tau^l}\hat{\tau}_t^l - \frac{\tau^c}{1+\tau^c}\hat{\tau}_t^c\right) \tag{3.13}$$

where we can see that depending on σ, the consumption of the non-Ricardian household will move in different proportions of the real wage after subtracting taxes.

By combining (3.12) and (3.13), we get:

$$\hat{N}_{H,t} = \frac{1-\sigma}{\sigma+\varphi}\left(\hat{w}_t - \frac{\tau^l}{1-\tau^l}\hat{\tau}_t^l - \frac{\tau^c}{1+\tau^c}\hat{\tau}_t^c\right) \tag{3.14}$$

which implies that depending on σ the income effect will dominate the substitution effect ($\sigma > 1$), the substitution effect will dominate the income effect ($\sigma < 1$), or both will be the same ($\sigma = 1$), for the labor supply of the non-Ricardian household.

Hence, to focus on a non-Ricardian household that always supply the same amount of labor and whose consumption tracks its real wage after subtracting taxes ('rule-of-thumb consumer'), we set $\sigma = 1$, which means that for the non-Ricardian household[1]:

$$\hat{N}_{H,t} = 0 \tag{3.15}$$

$$\hat{C}_{H,t} = \hat{w}_t - \frac{\tau^l}{1-\tau^l}\hat{\tau}_t^l - \frac{\tau^c}{1+\tau^c}\hat{\tau}_t^c \tag{3.16}$$

Combining these expressions with the linearized versions of the labor market condition, the production function, the labor supply of the Ricardian household and aggregate

[1] Also, by doing this, our results under distortionary taxation are comparable with the ones from Bilbiie (2008), as he makes a similar assumption.

consumption, we get:

$$\hat{C}_{S,t} = \frac{\lambda\varphi}{1-\lambda}\hat{a}_t - \frac{\lambda\varphi}{1-\lambda}\hat{Y}_t + \hat{C}_t \tag{3.17}$$

and by substituting the linearized version of the market clearing condition $\hat{Y}_t = s^c\hat{C}_t + s^g\hat{g}_t$ in (3.17) we derive the consumption function of the Ricardian household:

$$\hat{C}_{S,t} = \left(\frac{1}{s^c} - \frac{\lambda\varphi}{1-\lambda}\right)\hat{Y}_t + \frac{\lambda\varphi}{1-\lambda}\hat{a}_t - \frac{s^g}{s^c}\hat{g}_t \tag{3.18}$$

where we can see that Ricardian consumption has a positive relationship with productivity shocks, while having a negative relationship with government spending shocks.

Finally, substituting equation (3.18) into the linearized Euler equation of the Ricardian household, we derive the IS curve:

$$\begin{aligned}\hat{Y}_t = E_t\hat{Y}_{t+1} + \frac{\delta s^c}{1-\delta s^c}\left[E_t\hat{a}_{t+1} - \hat{a}_t\right] - \frac{s^g}{1-\delta s^c}\left[E_t\hat{g}_{t+1} - \hat{g}_t\right] + \frac{s^c}{1-\delta s^c}\frac{\tau^c}{1+\tau^c}\left[E_t\hat{\tau}^c_{t+1} - \hat{\tau}^c_t\right] \\ + \frac{s^c}{1-\delta s^c}\frac{\tau^b(1-\beta)}{1-\tau^b}E_t\hat{\tau}^b_{t+1} - \frac{s^c}{1-\delta s^c}\left[(1-\beta\tau^b)\hat{R}_t - E_t\hat{\pi}_{t+1}\right]\end{aligned} \tag{3.19}$$

where $\delta \equiv \frac{\lambda\varphi}{1-\lambda} > 0$.

3.2.1 Standard and inverted aggregate demand logic

We can see from the IS curve equation (3.19) that output and the real interest rate can have a negative or positive relationship, depending on the parameters of the model. If there is a negative relationship, implying a traditional downward-sloping IS curve, the economy follows the 'Standard Aggregate Demand Logic' (SADL). On the other hand, if there is a positive relationship, the economy follows an 'Inverted Aggregate Demand Logic' (IADL), as originally explained by Bilbiie (2008). Also, notice that if the economy follows the SADL, there will be a negative relationship between output and current productivity shocks, and a positive relationship between output and current government spending shocks; while under the IADL, output has a positive relationship with current productivity shocks, and a negative relationship with government spending shocks. Hence the transmission mechanism of fiscal shocks and productivity shocks are fundamentally different depending on whether the IS curve is upward or downward-sloping.

Consequently, for an economy to follow the SADL, it has to be the case that:

$$1 - \delta s^c > 0$$

$$\Rightarrow 1 - \left(\frac{\lambda\varphi}{1-\lambda}\right)\left(\frac{1-\tau^l}{1+\tau^c} + \frac{(1-\lambda)(1-\beta)s^b}{\beta(1+\tau^c)}\right) > 0 \tag{3.20}$$

where we substituted δ and s^c to derive an expression in terms of the parameters of the model. By inspection the bond-interest tax τ^b does not play a role in determining the shape of the IS curve described above. Instead, we can see that the slope of the aggregate demand curve depends on the values of the share of non-Ricardian households λ, the inverse of the Frisch elasticity φ, the income and consumption taxes τ^l and τ^c, and government debt as a share of output s^b.

From condition (3.20) we can implicitly define λ^* as the upper bound of the share of non-Ricardian agents such that the economy follows the SADL:

$$-\lambda^{*\,2}\varphi s^b + \lambda^*\left\{\frac{\beta}{1-\beta}[(1-\tau^l)\varphi + (1+\tau^c)] + s^b\right\} - \frac{\beta(1+\tau^c)}{1-\beta} = 0 \tag{3.21}$$

This expression implies that for values of $\lambda < \lambda^*$ the economy follows the SADL, which means that output has a negative relationship with the real interest rate; while for $\lambda > \lambda^*$ the economy follows the IADL, implying an upward-sloping IS curve.

By setting $\tau^l = \tau^c = s^b = 0$ in equation (3.21), we obtain the benchmark case condition for λ in an economy without distortionary taxation and government debt, which is the case explored by Bilbiie (2008). Solving for λ, we get the following expression:

$$\bar{\lambda} = \frac{1}{1+\varphi} \tag{3.22}$$

where $\bar{\lambda}$ denotes the upper bound of the share of non-Ricardian households λ that an economy without government can have in order to follow the SADL. It can be seen that $\bar{\lambda}$ is decreasing in the inverse of the Frisch elasticity φ. In other words, higher levels of labor supply elasticity imply a higher threshold for the share of non-Ricardian households in the benchmark case. As a consequence, for the SADL to operate, there must be a low λ and a high φ, or a high λ with a low φ. Therefore, an economy with a high share of non-Ricardian agents and a low labor supply elasticity will operate under the IADL.

3.2.2 The effect of fiscal policy on local dynamics

To analyze the effect of fiscal policy on the local dynamics of the model, we now consider equation (3.21) for different tax systems. For the income tax system, we set $\tau^c = 0$, while for the consumption tax system we set $\tau^l = 0$:

$$F^l(\lambda^l, \tau^l, s^b) = -\lambda^{l\,2}\varphi s^b + \lambda^l\left\{\frac{\beta}{1-\beta}[(1-\tau^l)\varphi + 1] + s^b\right\} - \frac{\beta}{1-\beta} = 0 \tag{3.23}$$

$$F^c(\lambda^c, \tau^c, s^b) = -\lambda^{c\,2}\varphi s^b + \lambda^c\left\{\frac{\beta}{1-\beta}[\varphi + 1 + \tau^c] + s^b\right\} - \frac{\beta(1+\tau^c)}{1-\beta} = 0 \tag{3.24}$$

where $F^l(\lambda^l, \tau^l, s^b)$ implicitly defines λ^l, which is the upper bound for λ under an income tax system, such that the economy follows the SADL; while for the consumption tax system, λ^c is the equivalent upper bound, implicitly defined by $F^c(\lambda^c, \tau^c, s^b)$.

To analyze the effects of φ, τ^l and s^b on λ^l, and the effects of φ, τ^c and s^b on λ^c, we use the implicit function theorem for each case. For the income tax system, we get:

$$\frac{\delta\lambda^l}{\delta\tau^l} = -\frac{\delta F^l/\delta\tau^l}{\delta F^l/\delta\lambda^l} = \frac{\frac{\beta}{1-\beta}\lambda^l\varphi}{-2\lambda^l\varphi s^b + \frac{\beta}{1-\beta}[(1-\tau^l)\varphi + 1] + s^b} \tag{3.25}$$

$$\frac{\delta\lambda^l}{\delta s^b} = -\frac{\delta F^l/\delta s^b}{\delta F^l/\delta\lambda^l} = \frac{\lambda^{l\,2}\varphi - \lambda^l}{-2\lambda^l\varphi s^b + \frac{\beta}{1-\beta}[(1-\tau^l)\varphi + 1] + s^b} \tag{3.26}$$

For $\frac{\delta\lambda^l}{\delta\tau^l} > 0$, it must be the case that:

$$2\lambda^l\varphi s^b < \frac{\beta}{1-\beta}[(1-\tau^l)\varphi + 1] + s^b$$

$$\Rightarrow \lambda^l < \frac{\beta}{1-\beta}\left(\frac{(1-\tau^l)\varphi + 1}{2\varphi s^b}\right) + \frac{1}{2\varphi} \tag{3.27}$$

which always holds if one of the following conditions is verified:

$$\varphi \leq \frac{1}{2} \tag{3.28}$$

$$s^b \leq \frac{\beta}{1-\beta}\left(\frac{\varphi(1-\tau^l) + 1}{2\varphi - 1}\right), \quad \text{for } \varphi > \frac{1}{2} \tag{3.29}$$

Conditions (3.27)-(3.29) show how for the income tax τ^l to have a positive effect on the upper bound of the share of non-Ricardian households that allows the SADL λ^l, such that $\frac{\delta\lambda^l}{\delta\tau^l} > 0$, there must be either a high labor supply elasticity (low φ) or a low level of government debt s^b.

On the other hand, considering expression (3.26), for λ^l to be increasing in s^b, such that $\frac{\delta\lambda^l}{\delta s^b} > 0$, in addition to (3.28) or (3.29), the next condition must hold:

$$\lambda^{l\,2}\varphi - \lambda^l > 0$$

$$\Rightarrow \lambda^l > \frac{1}{\varphi} \tag{3.30}$$

This condition implies that if $\varphi \, \epsilon \, (0, 1]$, then it will always be the case that $\lambda^l \leq \frac{1}{\varphi}$, for which (3.30) would not hold. As a consequence, $\frac{\delta \lambda^l}{\delta s^b} \leq 0$, which means that the upper bound of the share of non-Ricardian households that allows the SADL to operate λ^l is decreasing in the government debt s^b. On the other hand, if $\varphi > 1$ and condition (3.30) holds, then $\frac{\delta \lambda^l}{\delta s^b} > 0$, i.e., λ^l is increasing in s^b.

By a similar procedure, for the consumption tax system, we get:

$$\frac{\delta \lambda^c}{\delta \tau^c} = -\frac{\delta F^c / \delta \tau^c}{\delta F^c / \delta \lambda^c} = \frac{\frac{\beta}{1-\beta}(1 - \lambda^c)}{-2\lambda^c \varphi s^b + \frac{\beta}{1-\beta}[1 + \tau^c + \varphi] + s^b} \tag{3.31}$$

$$\frac{\delta \lambda^c}{\delta s^b} = -\frac{\delta F^c / \delta s^b}{\delta F^c / \delta \lambda^c} = \frac{\lambda^{c\,2} \varphi - \lambda^c}{-2\lambda^c \varphi s^b + \frac{\beta}{1-\beta}[1 + \tau^c + \varphi] + s^b} \tag{3.32}$$

As in the previous case, for $\frac{\delta \lambda^c}{\delta \tau^c} > 0$, it must be the case that:

$$2\lambda^c \varphi s^b < \frac{\beta}{1-\beta}[1 + \tau^c + \varphi] + s^b$$

$$\Rightarrow \lambda^c < \frac{\beta}{1-\beta} \left(\frac{1 + \tau^c + \varphi}{2\varphi s^b} \right) + \frac{1}{2\varphi} \tag{3.33}$$

which always holds if one of the following conditions verifies:

$$\varphi \leq \frac{1}{2} \tag{3.34}$$

$$s^b \leq \frac{\beta}{1-\beta} \left(\frac{1 + \tau^c + \varphi}{2\varphi - 1} \right), \quad \text{for } \varphi > \frac{1}{2} \tag{3.35}$$

As in the income tax case, this conditions imply that either for a low φ or a low s^b, the upper bound of the share of non-Ricardian households that allows the SADL to operate λ^c is increasing in the consumption tax τ^c.

Similarly, we get $\frac{\delta \lambda^c}{\delta s^b} > 0$ if (3.34) or (3.35) holds, along with:

$$\lambda^{c\,2} \varphi - \lambda^c > 0$$

$$\Rightarrow \lambda^c > \frac{1}{\varphi} \tag{3.36}$$

Hence, if $\varphi \, \epsilon \, (0, 1]$, it will always be the case that $\lambda^c < \frac{1}{\varphi}$, which implies λ^c to be decreasing in s^b. While if $\varphi > 1$ and (3.36) holds, λ^c is increasing in s^b.

The results suggest that with low levels of φ and s^b, distortionary taxation increases the threshold for the IADL. In other words, distortionary taxation decreases the possibility of an economy to operate under the IADL. From comparing (3.25) and (3.31), we can see that whether the income or the consumption tax has a bigger impact on the corresponding threshold for the share of non-Ricardian households that allows the SADL to operate depends on the value of the inverse of the Frisch elasticity φ. As we can see from (3.25) the effect of τ^l affects λ^l in a proportion defined by φ, while in (3.31) we can see that τ^c affects λ^c in its entire proportion. Therefore, for a $\varphi > 1$, the effect of τ^l on λ^l is greater than the effect of τ^c on λ^c. By a similar argument, comparing (3.26) and (3.32), with a $\varphi > 1$, the effect of s^b on λ^l is greater than the effect of s^b on λ^c.

As Bilbiie (2008) showed, φ and λ play a crucial role for determining dynamics in a model with lump-sum taxation. However, here we show not only the role of φ for determining the threshold of the share of non-Ricardian households that allows the SADL to operate, but also the role of different tax systems and the degree of government debt.

3.3 Calibration

The model is calibrated for the Mexican economy. Most of the parameters, autocorrelation coefficients for the shocks and steady state values are obtained from the existing literature. We define two sets of parameters, which vary in the share of non-Ricardian households λ and the inflation response coefficient μ_π, in order to generate an economy following the SADL and another one following the IADL, allowing us to compare both scenarios. The calibration of the model is summarized in Table 3.2.

As mentioned in the last section, for focusing on the role of the heterogeneous agents and the fiscal policy instruments, we set the risk-aversion coefficient $\sigma = 1$. Following the Bayesian estimates for Mexico of McKnight, Mihailov and Rangel (2020), we set the inverse of the Frisch elasticity to $\varphi = 1.47$ and the persistence of the productivity shock to $\rho_a = 0.64$. Kochen and Sámano (2016) found that there is a price duration of 10.1 months for Mexico, which implies a price stickiness coefficient of $\theta = 0.70$ for a quarterly calibration. Also, following Kochen (2016), who estimates a model to analyze price-setting and monetary shocks in Mexico, we set the elasticity of substitution between intermediate goods to $\varepsilon = 4$, implying a markup of 33%, which is consistent with the estimates of Castañeda-Sabido and Mulato (2006) of 31% for different industrial activities in Mexico.

For the monetary policy we consider two different scenarios. On the one hand, we set the monetary policy response coefficients following Moura and de Carvalho (2010), whose estimates of a Taylor rule for Mexico imply a quarterly inflation response coefficient of

$\mu_\pi = 0.6$, while finding that the output response coefficient was not statistically significant. These results are in line with Galindo and Guerrero (2003), which found an inflation response coefficient of 0.65 and that the output response coefficient μ_Y was not statistically significant. Consequently, we set $\mu_Y = 0$. While, on the other hand, we set $\mu_\pi = 1.2$ and $\mu_Y = 0$ to compare the first results, which follow the IADL, with a scenario that follows the SADL.

Table 3.2. Baseline parameter values

Parameter		Value
β	Discount factor	0.987
σ	Risk-aversion coefficient	1
φ	Inverse of the elasticity of labor supply	1.47
ε	Elasticity of substitution between intermediate goods	4
θ	Price stickiness	0.70
λ	Share of non-Ricardian agents	0.8, 0.3
μ_π	Inflation response coefficient	0.6, 1.2
μ_Y	Output response coefficient	0
ρ_a	Autocorrelation of productivity shock	0.64
ρ_x	Autocorrelation of monetary shock	0.50
ρ_g	Autocorrelation of government spending shock	0.50
τ^c	Steady state consumption tax	0.068
τ^l	Steady state income tax	0.127
τ^b	Steady state bond interest tax	0.127
s^b	Steady state ratio of government debt to output	1.6

For the income and consumption tax rates, steady state values are set according the estimations of Alba and McKnight (2020) for Mexico, namely, we set the steady state consumption tax $\tau^c = 0.068$ and the steady state income tax $\tau^l = 0.127$. It is assumed that the income tax rate equals the bond interest tax rate, i.e., $\tau^l = \tau^b = 0.127$. Following Aguiar and Gopinath (2007), we set $s^b = 1.6$, implying an annual public debt-to-output level of 40%, in line with the estimation of Alba and McKnight (2020) of 41%.

Setting $\beta = 0.987$, along with $\tau^b = 0.127$, we obtain a steady state nominal interest rate of around 6 percent, in line with the quarterly average rate of the CETES 28 for the 2001-2019 period (6.16%), and consistent with Aguiar and Gopinath (2007), who set $\beta = 0.98$.

The share of non-Ricardian agents in the economy, $\lambda = 0.8$, was estimated using data from the National Household Income and Expenditure Survey (ENIGH) from 1998 to 2018.

We considered the households that did not receive any monetary perception from financial and capital accounts (from both formal and informal sources), finding stable values along the period. By following this approach, we obtain a more accurate measure of the households that do not access financial markets, rather than simply considering the households that do not have a credit account. If this second approach was followed, the share of non-Ricardian agents would fall to 0.7, as reported in the results of the ENIF 2018 or the data from Findex 2017 presented in the introduction. Additionally, we consider a scenario under the SADL by setting $\lambda = 0.3$. Finally, the persistence of the monetary and government spending shock are set to $\rho_x = 0.50$ and $\rho_g = 0.50$ by assumption.

With these parameter values, we can compute the thresholds for the share of non-Ricardian households, mentioned in the last section, for the different tax systems:

$$\begin{aligned} \bar{\lambda} &= 0.4048 \\ \lambda^l &= 0.4346 \\ \lambda^c &= 0.4195 \end{aligned}$$

It can be seen that, for our given parameterization, distortionary taxation increases the threshold under which the economy operates under the IADL. By this result, distortionary taxation decreases the possibility of the economy to operate under the IADL. It is also clear that the income tax system implies a higher threshold than the consumption tax system. These results show how the $\lambda = 0.8$, estimated for the Mexican economy, is above the thresholds and implies that the Mexican economy operates under the IADL. On the other hand, the alternative value for $\lambda = 0.3$ is below the thresholds, which implies that modifying this parameter allows us to analyze the model dynamics under the SADL.

For determinacy reasons, which will be discussed in the next chapter, we set two different values for μ_π. For the IADL we use the estimation of the inflation response coefficient for Mexico $\mu_\pi = 0.6$, while for the SADL we set $\mu_\pi = 1.2$. The two sets of parameters will allow us to compare the dynamics of two different systems of aggregate demand and to analyze the role of asset market participation and fiscal policy.

Chapter 4

Determinacy analysis

This chapter explores the impact of heterogeneous agents and distortionary taxation on determinacy. As it is well known, the design of monetary policy rules has important implications on equilibrium determinacy. Some rules can induce instability through indeterminacy, as they generate self-fulfilling expectations in the economy, which could cause important welfare losses.

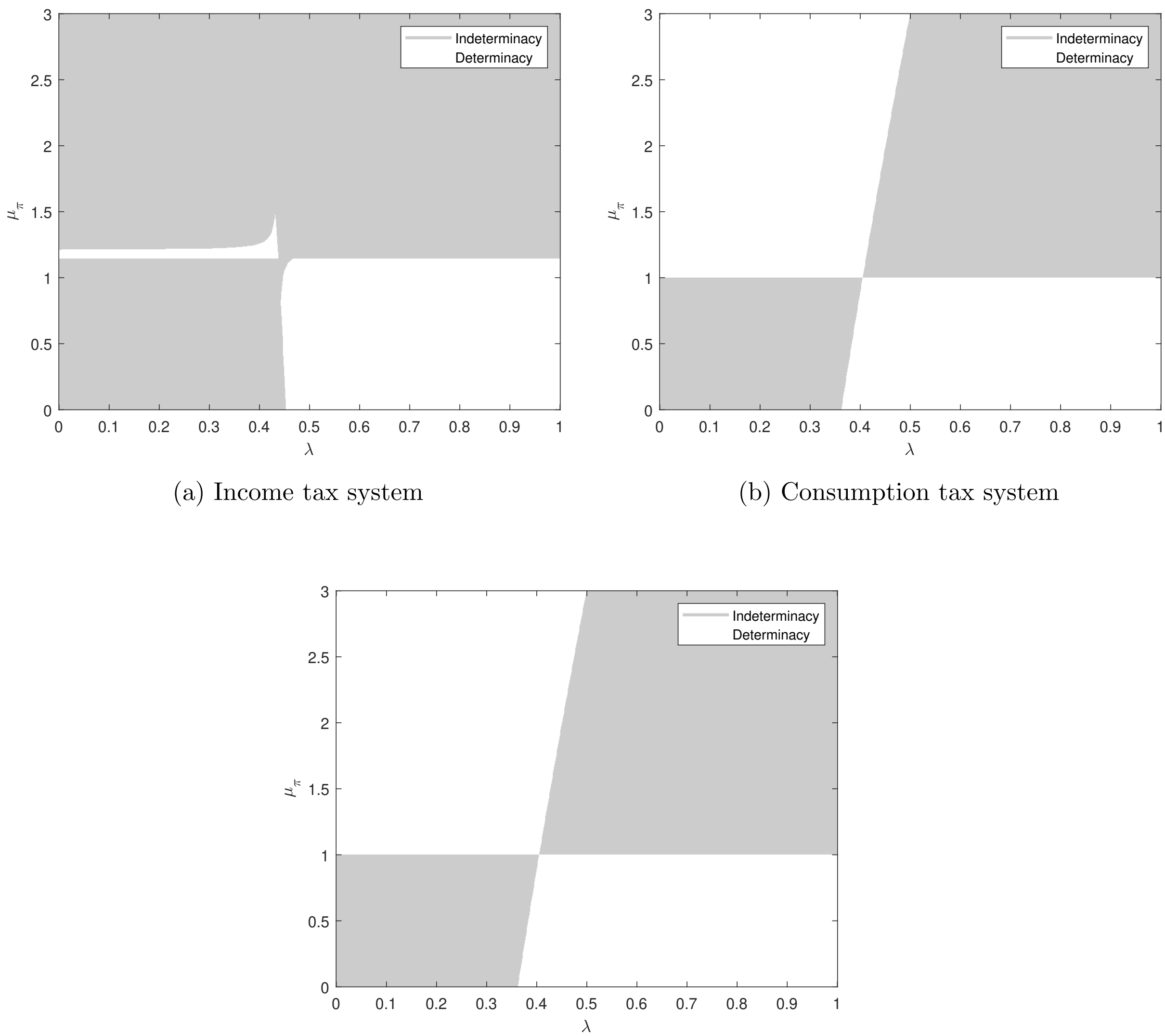
In the standard model without distortionary taxation, which we represent under the SADL, a monetary policy rule following the Taylor principle generates equilibrium determinacy. In this case, the monetary authority adjust the nominal interest rate more than proportionally to inflation, such that the real interest rate rises, with a contractionary effect on aggregate demand that prevents self-fulfilling expectations.

However, introducing heterogeneous agents in a New-Keynesian model has important determinacy implications, and a policy rule following the Taylor principle might not be appropriate in certain cases. As we showed in the previous chapter, in a framework without government, the share of non-Ricardian households λ and the inverse of labor supply elasticity φ determine the shape of the IS curve and thus thus have important implications for the local dynamics of the model economy.

Furthermore, we have shown that introducing distortionary taxes and government debt in the model has an effect on the threshold of λ that allows IADL to operate, given a certain level of φ. Therefore, not only the share of non-Ricardian agents and the labor supply elasticity are relevant for determinacy, but also distortionary taxes and government debt, as shown by McKnight (2017) using a standard New Keynesian model with homogeneous agents.

4.1 Baseline parameter values

The determinacy analysis suggests that the model is prone to two different sources of indeterminacy: asset market participation and distortionary taxation. Figure 4.1 shows the determinacy regions using our baseline parameterization for the different tax systems. We consider a benchmark case with lump-sum taxation, with a forward-looking interest-rate policy rule. The lump-sum taxation case is achieved by setting $\hat{\tau}_t^l = \hat{\tau}_t^b = \hat{\tau}_t^c = \tau^l = \tau^b = \tau^c = 0$ for all t; for the income tax system we set $\hat{\tau}_t^c = \tau^c = 0$ and $\hat{\tau}_t^l = \hat{\tau}_t^b$ for all t, while for the consumption tax system we set $\hat{\tau}_t^l = \hat{\tau}_t^b = \tau^l = \tau^b = 0$ for all t.



(a) Income tax system

(b) Consumption tax system

(c) Lump-sum taxation

Figure 4.1. Determinacy regions under different different tax systems

It can be seen for the three cases in Figure 4.1, how the two shapes of the IS curve pointed out by Bilbiie (2008) operate in the model. For certain values of λ from 0 to around 0.4, the economy operates under the SADL. For the income tax system, the lower bound of the inflation response coefficient that allows determinacy is higher than in the other cases, where the Taylor principle operates for a low share of non-Ricardian agents. For higher values of λ, the economy operates under the IADL, where the central bank must implement a passive monetary policy to achieve determinacy. This policy is called by Bilbiie the 'Inverted Taylor Principle', which implies that given an upward-sloping IS curve, the central bank must conduct a passive monetary policy in order to achieve determinacy, i.e., to achieve economic stability.

By inspection, the income tax system implies smaller regions of determinacy than the consumption tax system, which gives a glimpse of the benefits of the consumption tax over income taxation. Panel (a) shows how constrained monetary policy is when trying to achieve equilibrium determinacy under this level of government debt $s^b = 1.6$ and income tax rate $\tau^l = 0.127$. Also, it is worth noting that under the income tax system, there are values of λ for which a strict forward-looking inflation-targeting policy cannot achieve determinacy under any case. However, note that the determinacy region of IADL seems smaller here than with lump-sum taxation, as we would expect from the discussion of section 3.3. Furthermore, comparing Panel (b) and (c), we can see that there is not a visible effect of consumption taxation on the determinacy regions.[1]

As we showed in the previous chapter, distortionary taxes and government debt affect the upper bound of λ that allows the SADL to operate. Hence, fiscal policy has important determinacy implications. In the next sections we analyze the variations in the steady state tax rates and the government debt-output ratio on determinacy.

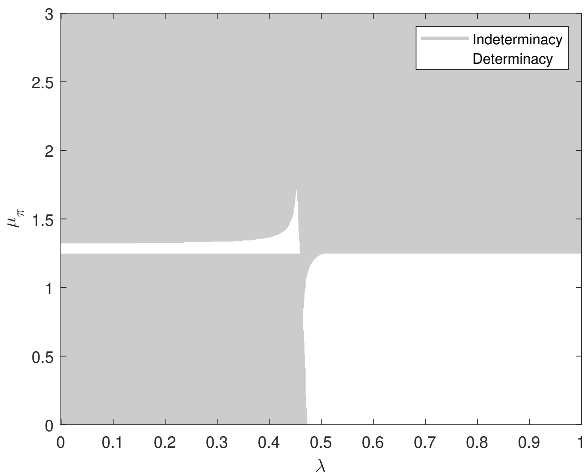
4.2 Variations in the steady state tax rates

We now analyze the effect of distortionary taxation on determinacy by modifying the steady state tax rates while keeping the rest of the parameters constant.

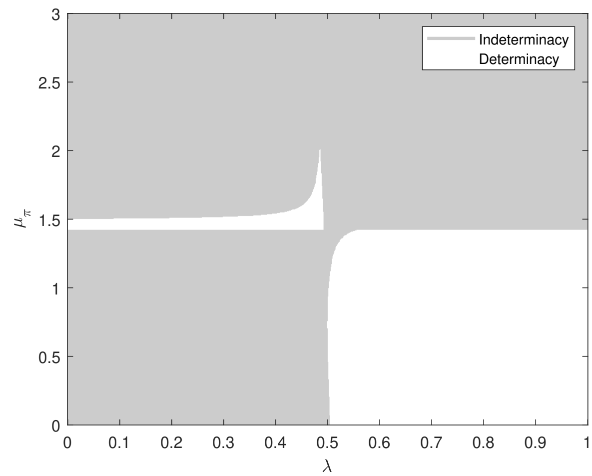
Figure 4.2 shows the determinacy regions under different income tax rates by setting different steady state levels for the income tax, namely $\tau^l = 0.2,\ 0.3$ and 0.4. It can be seen that increasing this tax, heightens the lower and upper bounds of the inflation response coefficient under the SADL, as we are considering the case where $\tau^l = \tau^b$. This result is

[1]It is important to mention that this result is probably due to setting $\sigma = 1$ (McKnight, 2017). Also, the results in this section strongly depend on the form of the monetary policy rule that we assumed, which means that considering a current-looking rule or an output response coefficient $\mu_Y > 0$ would change the determinacy regions.

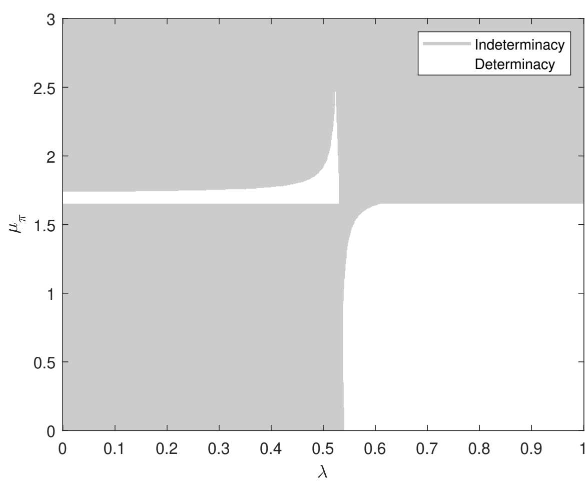
in line with McKnight (2017), who showed how increasing the steady state tax rate has a similar effect when considering the different combinations of μ_π and s^b. Also, as the income tax rate increases, so does the lower bound of the share of non-Ricardian agents that allows the IADL to operate. This implies that the distortionary income tax reduces the possibility of the economy to operate under the IADL, which is consistent with the finding in the previous chapter that λ^l was increasing in τ^l for low values of s^b, as we are considering here.



(a) $\tau^l = 0.2$



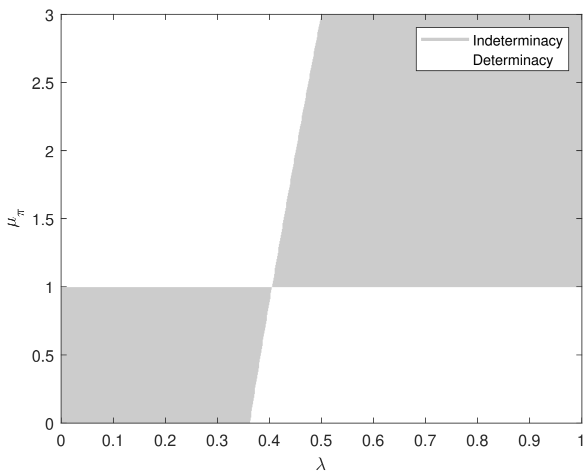
(b) $\tau^l = 0.3$



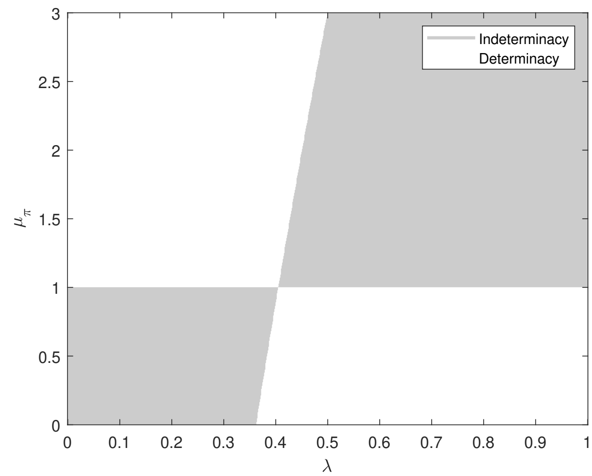
(c) $\tau^l = 0.4$

Figure 4.2. Determinacy regions under different income tax rates

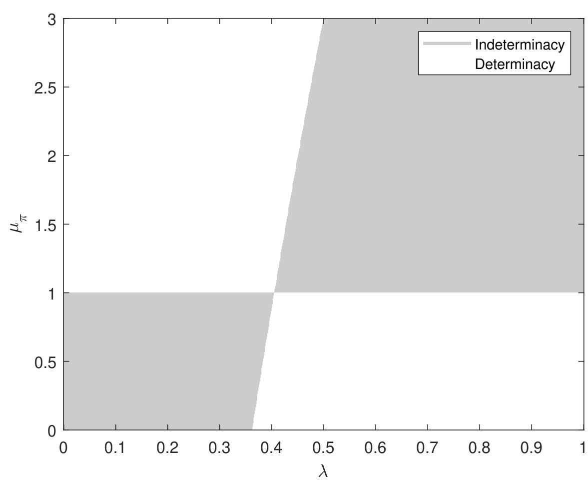
Hence, with low levels of government debt, higher income tax rates allow for lower asset-market participation in the economy while still getting the SADL. However, there is a slightly wider area for which this monetary policy cannot achieve determinacy. Consequently, a higher income tax rate also reduces the range for λ under which IADL operates, while setting a higher upper bound for μ_π, implying a broader range for monetary policy than with the inverted Taylor principle. By these result, under an income tax system that includes bond interest taxation, monetary policy can be either passive or active under the IADL, i.e., it can follow the Taylor principle and the inverted Taylor principle.



(a) $\tau^c = 0.05$



(b) $\tau^c = 0.15$



(c) $\tau^c = 0.25$

Figure 4.3. Determinacy regions under different consumption tax rates

Notice that increasing the income tax rate broadens the determinacy region under the SADL, while also shifting it upwards. This effect implies a shifting in the lower and upper bounds of the inflation response coefficient of monetary policy μ_π needed for achieving determinacy. Considering these levels of taxation and government debt, it is needless to say that the Taylor principle is not enough to achieve determinacy. As we will see in the next section the upper bound restriction for μ_π is not only related to τ^l, but also to the government debt level s^b.

By contrast, Figure 4.3 presents the determinacy regions for a consumption tax system under different steady state tax rates. We set $\tau^c = 0.05,\ 0.15$ and 0.25. It can be seen that higher consumption tax rates do not have a visible effect on the determinacy regions. As for the case of the area where SADL operates, the results are in line with McKnight (2017), who showed how in a standard model the upper bound of the inflation response coefficient μ_π that allows for determinacy is independent of the steady state level of the consumption tax with $\sigma = 1$, as it is the case here.

Comparing both effects of the taxes on determinacy, we can see how, as we set $\varphi = 1.47$, the effect of the income tax τ^l on determinacy is bigger than the effect of τ^c. This is consistent with the finding in the previous chapter, where with a $\varphi > 1$, the effect of τ^l on λ^l is greater than the effect of τ^c on λ^c. Hence, the income tax can reduces the possibility of the economy falling into the IADL. However, note that the determinacy regions under the income tax systems are considerably small. Therefore, the income tax system implies a trade-off between achieving the SADL and a bigger scope of action for monetary policy under the IADL, for economies with a share of non-Ricardian households close to the threshold.

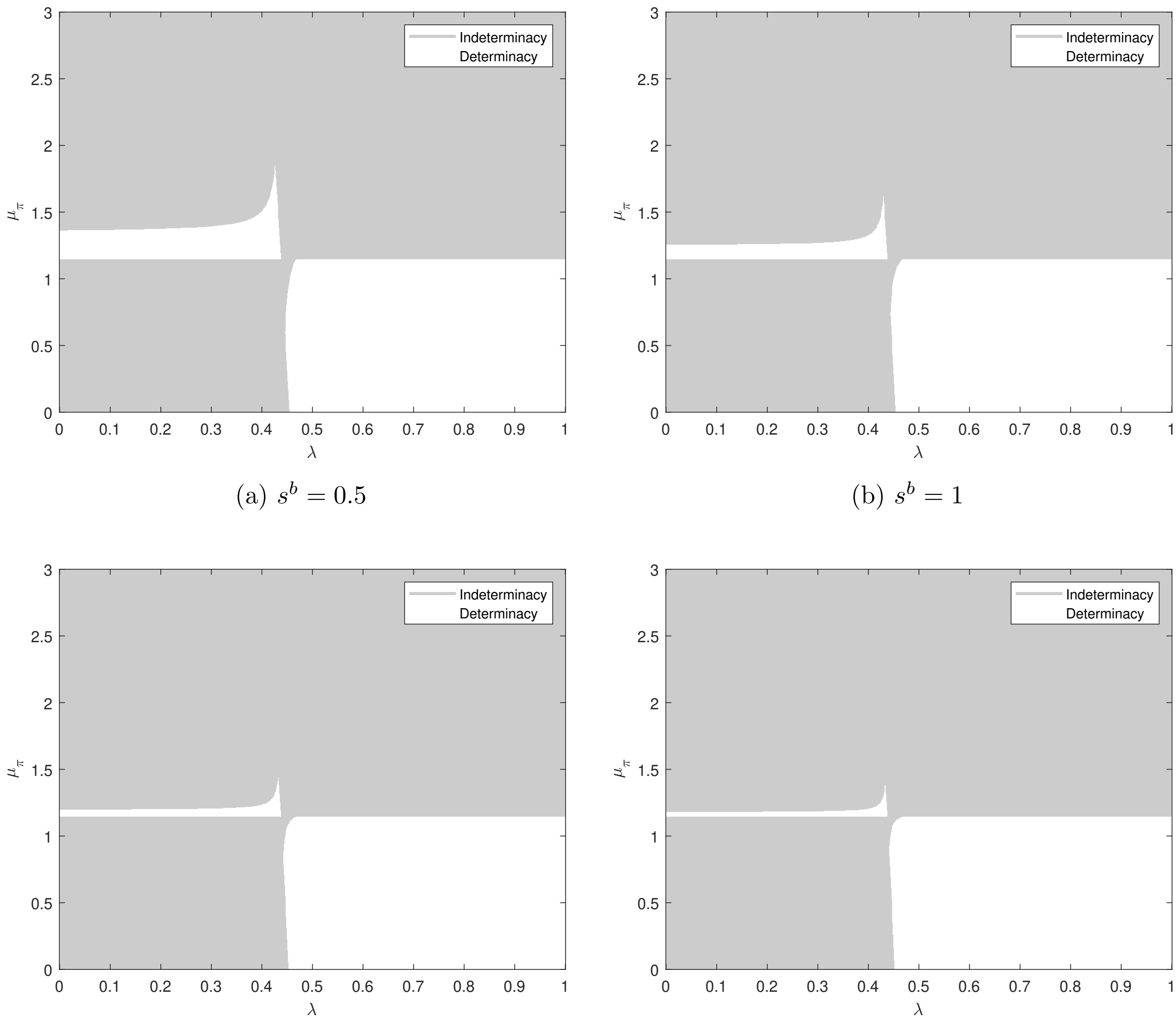
4.3 The effect of government debt

We now develop a similar analysis for both tax systems to study the effect of government debt on determinacy. We plot the determinacy regions under both tax systems for different steady state levels of government debt-output ratio, namely $s^b =\ 0.5,\ 1,\ 2$ and 3.

Figure 4.4 shows the determinacy regions for different levels of government debt s^b under the income tax system. First of all, it is worth noting that the effect of s^b on λ^l, showed in expression (3.26) in the previous chapter, is actually very small and close to zero, as the threshold for λ that dictate if the IADL operates does not seem to change along the four panels as the government debt increases.

The effect of government debt increases on determinacy consists of lower upper bounds for μ_π under the SADL. This implies that under the income tax system, increasing the government debt restricts the spectrum of response of monetary policy that achieves determinacy under the SADL. On the other hand, government debt does not seem to have an effect on the determinacy regions of an economy operating under the IADL.

From Figure 4.5 we can see that government debt has a very different effect under a consumption tax system. The effect of s^b on λ^c, captured by expression (3.32) in the previous chapter, seems to be minimum, as with the income tax system. It can be seen in the four panels that the threshold of λ that dictates whether the SADL or the IADL operate does not change for different levels of government debt, which in this case is around 0.4.

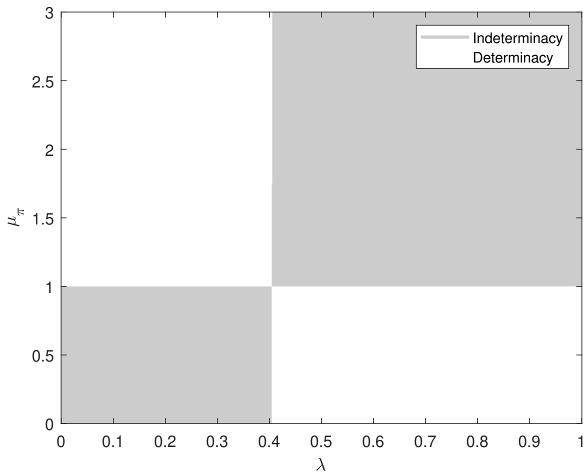


(a) $s^b = 0.5$ (b) $s^b = 1$

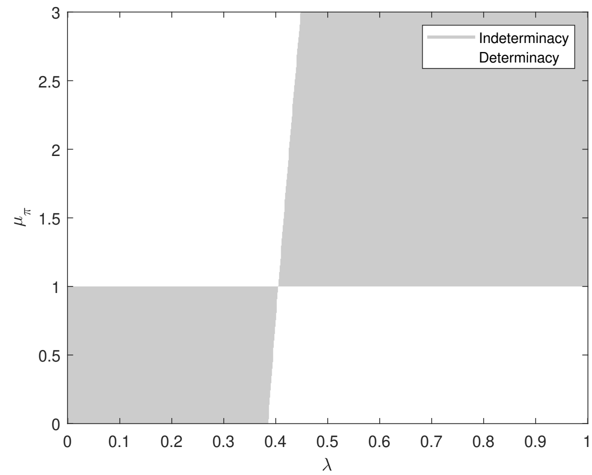
(c) $s^b = 2$ (d) $s^b = 3$

Figure 4.4. Determinacy regions under different government debt levels: income taxation

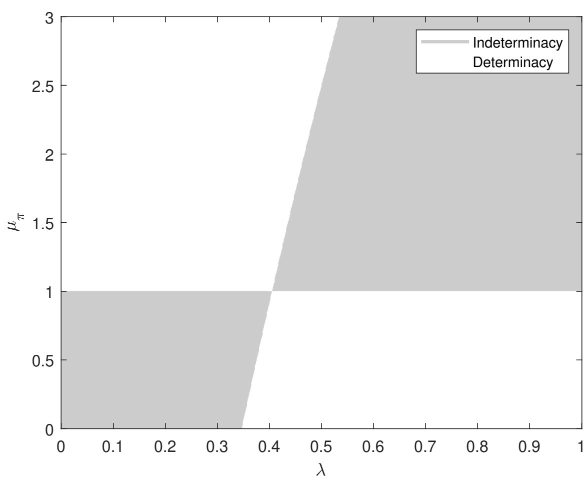
As mentioned before, the level of the consumption tax rate is not relevant for determining the upper bounds of monetary policy under the SADL. However, increasing the government debt broadens the determinacy regions, both under the SADL and the IADL. This implies that high levels of government debt in a consumption tax system allow for a bigger scope of action for the monetary authority to respond to inflation. Furthermore, note that for $s^b > 0.50$ there are some values of λ for which a strict forward-looking inflation-targeting policy can respond actively or passively to inflation.



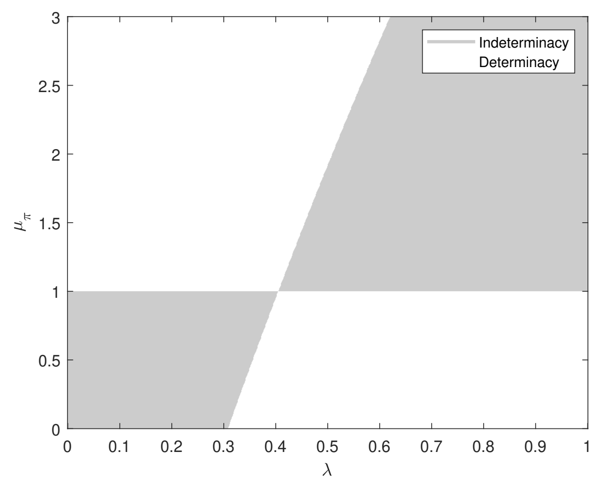
(a) $s^b = 0.5$



(b) $s^b = 1$



(c) $s^b = 2$



(d) $s^b = 3$

Figure 4.5. Determinacy regions under different government debt levels: consumption taxation

Considering the results analyzed in this chapter, we highlight the following aspects of the effects of fiscal policy on determinacy. There is not much difference in the determinacy regions between the consumption tax system and the lump-sum taxation case. Focusing on the SADL case, the consumption tax system seems preferable to the income tax systems as it implies greater determinacy regions, and since government debt does not have a visible effect on determinacy. By contrast, under the income tax system, determinacy regions are considerably small, and as the steady state government debt-output ratio rises they get even smaller. However, the income tax system has a much bigger impact on reducing the range of heterogeneous agents required for the IADL to operate when increasing the steady state tax rate. Hence, the income tax system reduces the possibility of an economy to operate under the IADL. Furthermore, focusing on the IADL, increasing the steady state tax rate under the income tax system heightens the upper bound of the inflation response coefficient of the monetary policy rule, which implies a bigger scope of action for monetary policy and that it must not necessarily follow the inverted Taylor principle to achieve determinacy, as it can conduct an active monetary policy. Furthermore, under the IADL, government debt does not have an impact on determinacy under the income tax system. By this, the income tax system seems preferable for an economy operating under the IADL.

Chapter 5

Impulse response analysis

The dynamics of the model are analyzed for the income and consumption tax systems. For the income tax system we set $\hat{\tau}_t^c = \tau^c = 0$ for all t, while for the consumption tax system we set $\hat{\tau}_t^l = \hat{\tau}_t^b = \tau^l = \tau^b = 0$ for all t. As in the previous chapter, for the income tax system we consider the case where bond interest income is taxed at the income tax rate, which implies $\tau^l = \tau^b$ and $\hat{\tau}_t^l = \hat{\tau}_t^b$ for all t. The rest of the parameters and output shares are the same for both systems.

We consider three different shocks to productivity, monetary policy and government spending as specified in previous chapters. For each shock, we discuss the role of heterogeneous agents and the role of each tax system. Additionally, for each set of dynamics, we show two different results. The first one consists of an economy under the SADL, which we attain by setting $\lambda = 0.3$, i.e., a low share of non-Ricardian households, and by considering a monetary policy that follows the Taylor principle, setting $\mu_\pi = 1.2$ and $\mu_Y = 0$. This monetary policy is adopted for achieving determinacy in both tax systems. On the other hand, the second set of dynamics is entirely based on the Mexican economy, setting $\lambda = 0.8$ and $\mu_\pi = 0.6$. As a consequence, the Mexican economy would be operating under the IADL, but determinacy is still achieved by following the inverted Taylor principle. Therefore, we can compare the results under IADL against the results of the SADL.

5.1 Productivity shocks

We start by analyzing the effect of a positive productivity shock under the income tax system. Figure 5.1 shows the impulse response functions for a positive 1% productivity shock under the SADL and IADL for this tax system. Under the SADL the productivity shock has a negative effect on the marginal cost and the real wage, which increases the dividends from the Ricardian households, given the higher profits for the firms. The fall in the marginal cost reduces inflation, and with a forward-looking monetary policy rule, this results in a lower real interest rate. This means that Ricardian households can now borrow at a lower rate. This mechanisms take the Ricardian households to reduce their labor supply and increase their consumption.

On the other hand, as the non-Ricardian households cannot adjust their labor supply, and given that they cannot access the financial market, their employment remains constant. Thus aggregate employment falls due to the reduction in Ricardian employment. As the real wage falls, non-Ricardian households have a lower income, which reduces their consumption. Even though non-Ricardian households represent only 30% of the population, aggregate consumption falls, as the negative effect on non-Ricardian consumption exceeds the positive effect on Ricardian consumption. Consequently, aggregate output falls by the fall in aggregate employment. As lower output implies a smaller tax base, the fiscal authority reacts by increasing the income tax rate, in order to maintain a balanced budget.

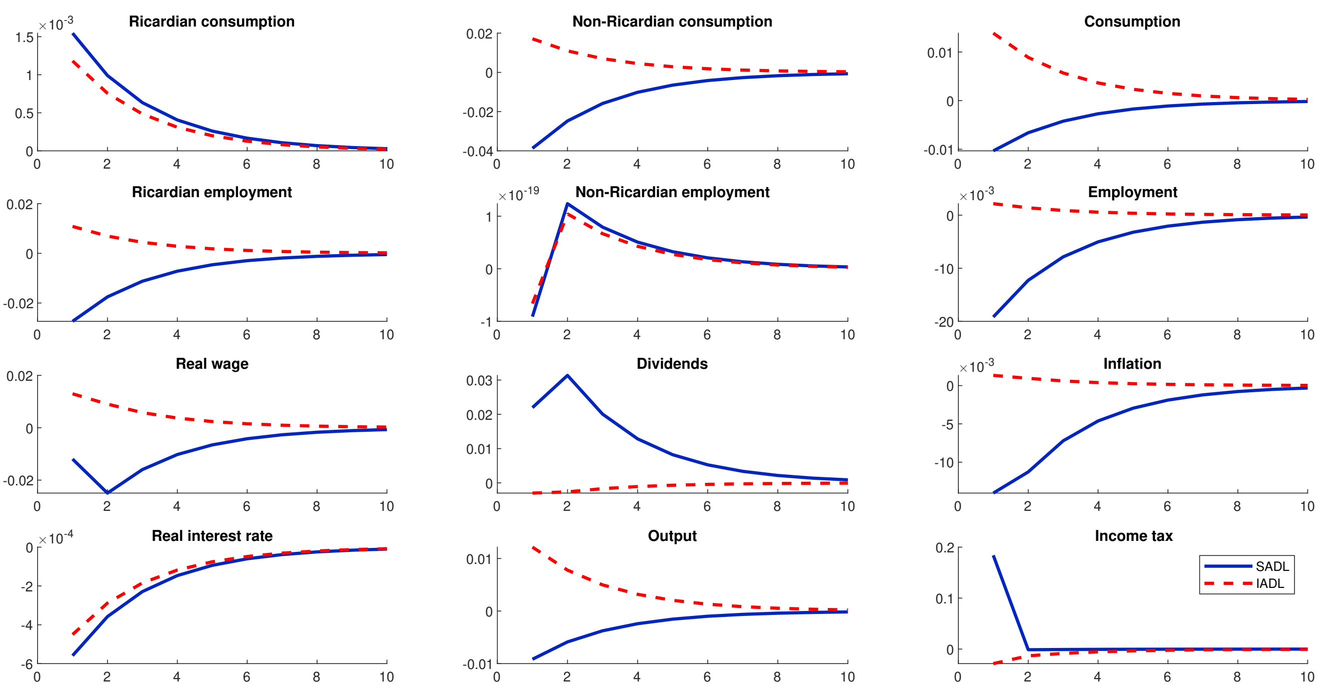


Figure 5.1. Impulse responses for a positive 1% productivity shock under the income tax system

Now consider the case where the IADL operates. The productivity shock has a positive effect on labor demand, while also downward pressuring the marginal cost and hence wages for a given level of employment. However, as only 20% of the population, represented by the Ricardian households, can adjust their labor supply, in this case the demand effect dominates the downward pressure on wages. As a consequence, the productivity shock has a positive effect on real wages through labor demand. With higher wages, Ricardian households supply more hours to the labor market, which implies a (lower) rise in aggregate employment. Given this mechanism, marginal cost ends up increasing instead of falling as in the SADL case. This generates a small fall in dividends, ameliorated by the higher output level, given the increase in employment. With higher marginal costs, inflation rises, which with a passive monetary policy rule implies a lower real interest rate. With this effect Ricardian households increase present consumption. Moreover, with the increase in real wages, non-Ricardian households can enjoy from a higher consumption, with an overall rise in aggregate consumption. Finally, as the output level rose, so did the tax base, which allows the government to reduce the income tax rate.

This analysis shows how under an income tax system and different degrees of asset market participation, we can get a different transmission mechanism for productivity shocks on most of the macroeconomic variables. To better understand these results, recall the IS curve derived in Chapter 3:

$$\begin{aligned}\hat{Y}_t = E_t\hat{Y}_{t+1} &+ \frac{\delta s^c}{1-\delta s^c}\left[E_t\hat{a}_{t+1} - \hat{a}_t\right] - \frac{s^g}{1-\delta s^c}\left[E_t\hat{g}_{t+1} - \hat{g}_t\right] + \frac{s^c}{1-\delta s^c}\frac{\tau^c}{1+\tau^c}\left[E_t\hat{\tau}^c_{t+1} - \hat{\tau}^c_t\right] \\ &+ \frac{s^c}{1-\delta s^c}\frac{\tau^b(1-\beta)}{1-\tau^b}E_t\hat{\tau}^b_{t+1} - \frac{s^c}{1-\delta s^c}\left[(1-\beta\tau^b)\hat{R}_t - E_t\hat{\pi}_{t+1}\right]\end{aligned}$$

It can be seen from the IS curve, that for the SADL, the model predicts a negative relationship between output and the productivity shock, while for the IADL we get a positive relationship.

The transmission mechanism of productivity shocks under the consumption tax system is very different to the results from the income tax system. For the productivity shocks we find that the magnitude of the effects is bigger for the SADL case, but most of the variables practically return to their steady state levels from the second period.

Under the SADL, a positive productivity shock stimulates labor demand and rises the real wage, which implies higher Ricardian (and aggregate) employment and higher non-Ricardian consumption (see Figure 5.2). By the rise in real wage, dividends fall and marginal cost rise, which increases inflation. As the central bank expects inflation to fall in the next period, the real interest rate falls, which makes Ricardian households to increase consumption. Hence aggregate consumption rises in the first period, which allows government to reduce the consumption tax rate due to the bigger tax base. It is worth noting that most of the rise in aggregate consumption comes from non-Ricardian consumption, which, even though there is a low share of these households, rises more than Ricardian consumption as it reacts directly to the real wage increase and the lower tax rate.

However, the Ricardian households expect higher taxes for the second period, which takes them to reduce their consumption in that period. As a consequence, aggregate demand falls and so does the real wage, which makes the Ricardian (and aggregate) employment to fall. With the lower real wage, non-Ricardian households consume less and aggregate consumption falls. By this mechanism, inflation falls in the second period, which is what the central bank expected during the previous period. Overall, the consumption tax acts as an automatic stabilization mechanism.

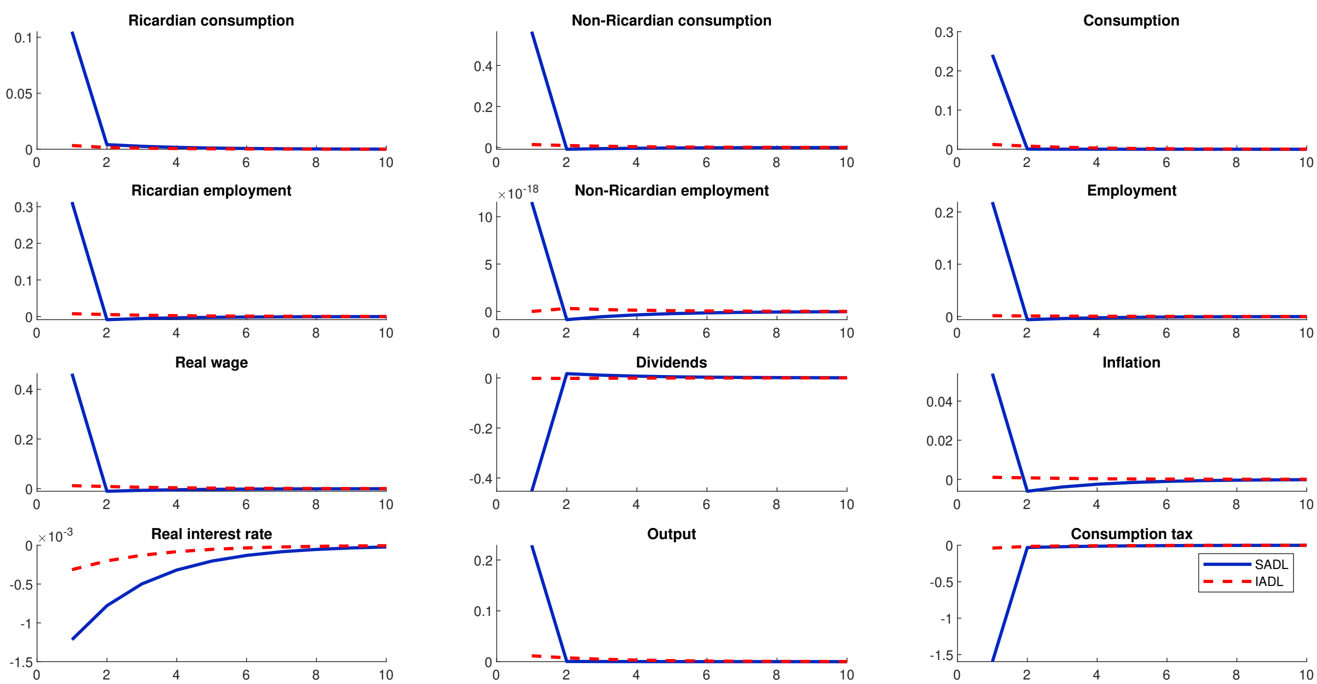


Figure 5.2. Impulse responses for a positive 1% productivity shock under the consumption tax system

Note that just changing the tax system under the SADL generates very different impulse responses. Under the income tax system, the productivity shock reduced output, consumption, employment and inflation; while under the consumption tax we observed exactly the opposite followed by an almost instant stabilization process. Note from the IS curve that under the SADL there is a negative relationship between the consumption tax and output. The fall in the consumption tax rate in the first period generates the positive effect on output after the productivity shock. This is the key difference between both tax systems, as the resulting dynamics depend on the indirect effect of the shock on aggregate demand.

From Figure 5.2 it can be observed how the big magnitudes of the effects under the SADL make it difficult to visualize the dynamics under the IADL. We represent the results under the IADL separately in Figure 5.3. By inspection, all the variables respond to the productivity shock in the same direction as in the SADL. Under the IADL there is a positive relationship between aggregate demand and productivity shocks, by the IS curve. Hence that positive effect incentives labor demand, raising the real wage and marginal cost. This generates the same dynamics as under the SADL, with the singularity that under the IADL the consumption tax does not act as an automatic stabilizer.

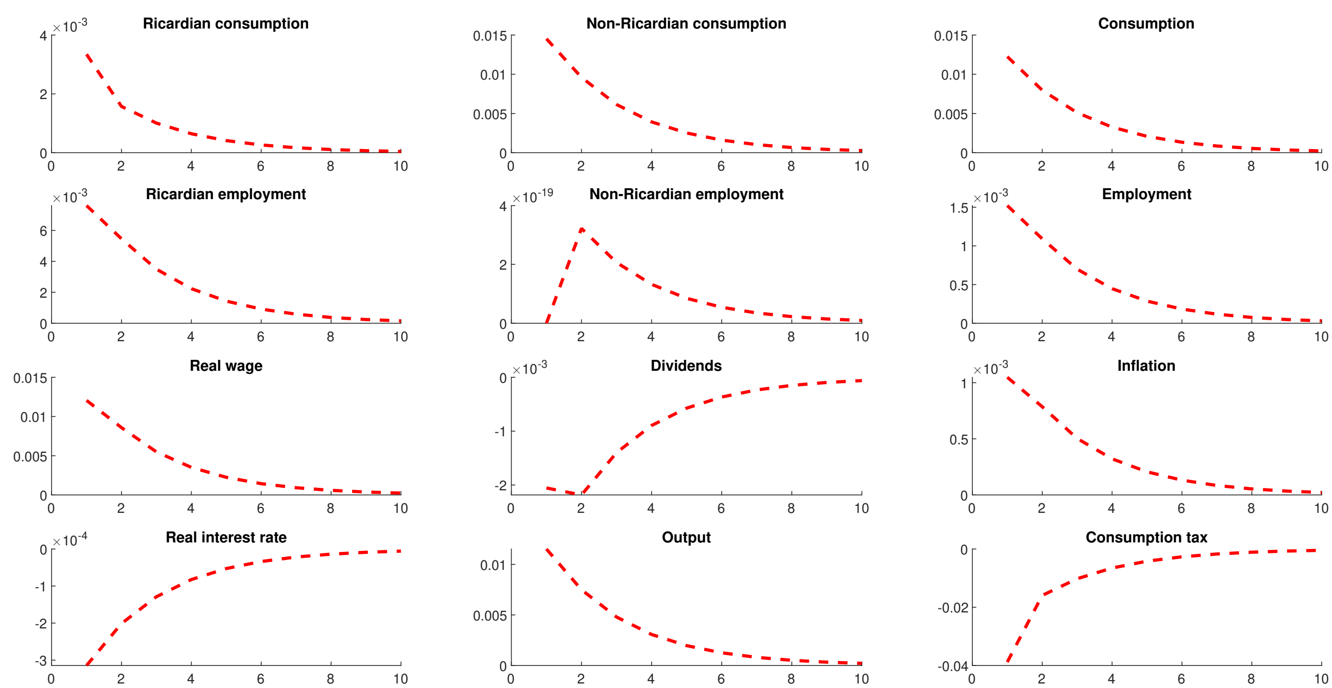


Figure 5.3. Impulse responses for a positive 1% productivity shock under a consumption tax system and the IADL

The reason for this to happen is that under the SADL there is a considerable level of asset market participation. This implies that more households can smooth consumption over time, and hence more households react to the future consumption tax rate, which accounts for the big fall in the resources allocation for the second period. In the IADL case this effect is ameliorated by the high share of non-Ricardian households. Even though Ricardian households smooth consumption over time and react to expected consumption taxes, this does not generate a significant effect on other variables, given the low share of Ricardian households. As a consequence, consumption and employment do not fall as much during the second period, with the same effect in the rest of the variables. Therefore, the economy smoothly returns to its steady state.

5.2 Monetary policy shocks

Now we analyze the case of a negative monetary shock, which best reflects the importance of the SADL and the IADL, specifically, how we can get a negative or positive relationship between output and the real interest rate. Figure 5.4 shows the impulse response functions for a negative 1% monetary policy shock under the income tax system. The monetary shock implies a higher real interest rate, which reduces present consumption of the Ricardian households in order to get a higher future consumption. As a consequence, given the high share of Ricardian households under the SADL, aggregate demand falls, resulting in a lower output level. This has a negative effect on labor demand, which reduces the real wage, resulting in a lower marginal cost, implying a fall in inflation and a rise in dividends. Therefore, Ricardian households reduce their labor supply. By the smaller tax base, the income tax rate rises. Given that non-Ricardian households cannot adjust their labor supply and real wages are lower, non-Ricardian consumption also falls. Overall the monetary shock reduces aggregate consumption, employment, the real wage, output and inflation. This results are in line with the negative relationship between output and the real interest rate implied by the downward-sloping IS curve for the SADL case.

Under the IADL we face a completely different mechanism. As before, the rise real interest rate makes the Ricardian household to substitute present for future consumption. However, as there is a low share of Ricardian households, the effect in aggregate demand is minimum, which cause a small fall in real wage for the first period, with a small rise in dividends. Given the fall in present consumption for the Ricardian households and the small effect on aggregate demand, the Ricardian households supply more labor hours. This implies higher aggregate employment, which increases output, as this effect dominates the reduction of aggregate demand. Consequently the tax base rises, which allows the government to reduce taxes. Therefore, there is a higher after-tax wage, which allows non-Ricardian households to increase consumption, resulting in an overall increase in aggregate consumption and aggregate demand.

For the second period, where the downward pressure of Ricardian consumption on aggregate demand is lower than in the first period, labor demand increases, which raises the real wage above the steady state level, with the consequent fall in dividends. This allows the non-Ricardian households to continue having a consumption above the steady state level. However, given that during this period the government must pay the first-period debt, which had a higher real rate, the income tax rate rises to maintain the balanced budget. After this period all the variables converge to the steady state.

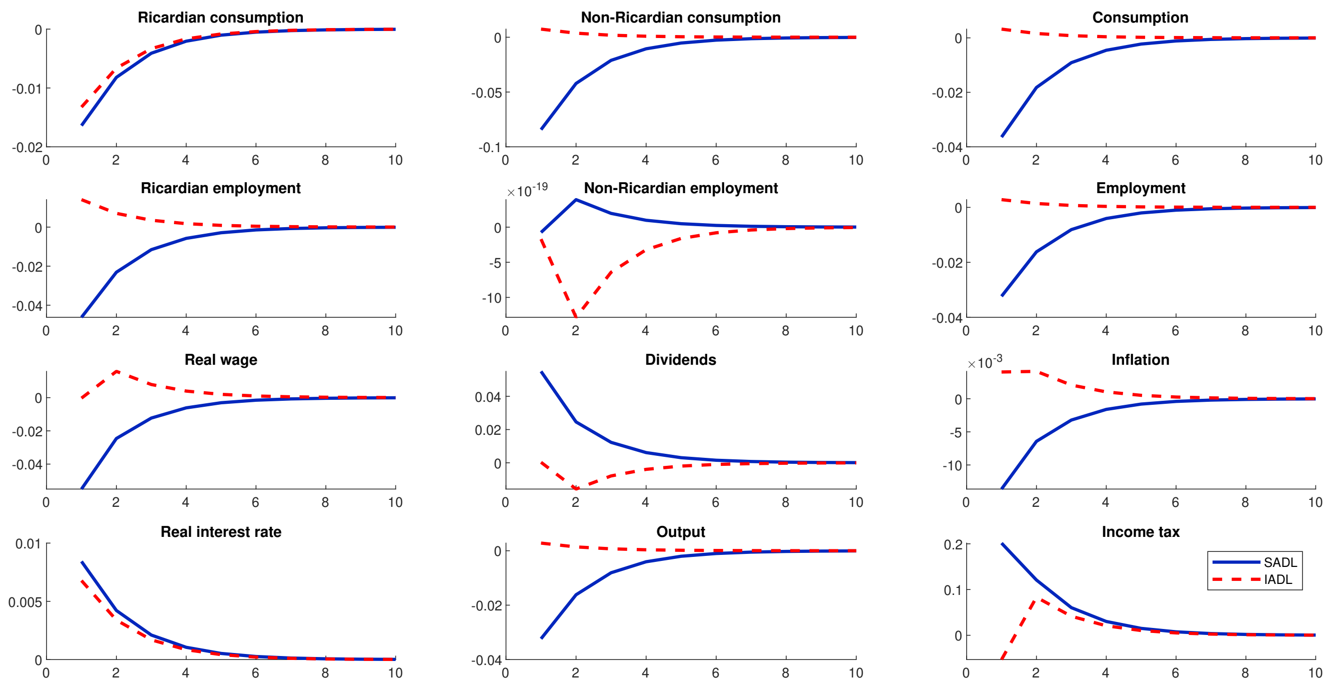


Figure 5.4. Impulse responses for a negative 1% monetary shock under the income tax system

Altogether the higher real interest rate generates higher levels of consumption, employment, output, real wage and inflation (driven by the expected higher marginal cost from the first period). However, it is worth noting that even though there is a positive relationship between the real interest rate and output, implied by the upward-sloping IS curve under the IADL, the effect is very small. Thus the model predicts a very small (but expansionary) effect on output after a contractionary monetary shock for the Mexican economy.

Figure 5.5 shows the impulse response functions for a negative 1% monetary policy shock under the consumption tax system. Under the SADL, the negative monetary shock raises the real interest rate. As Ricardian households expect that the government reacts by raising the consumption tax rate in the next period, they increase present consumption. This effect dominates the intertemporal substitution effect in consumption by the higher real interest rate. Consequently, aggregate demand rises, which has a positive effect on the real wage and the marginal cost. By this effect, Ricardian and aggregate employment increase. With a higher wage non-Ricardian households can consume more, which results in the rise of aggregate consumption, implying a broader tax base and a lower tax rate for the period. Also, by the higher aggregate demand, output and inflation rise for the first period. Notice how even under the SADL a positive relationship between the real interest rate and output can arise with a consumption tax system, even under a downward-sloping IS curve.

The second period, the same automatic mechanism of the consumption tax that we explained for the productivity shock acts to stabilize the economy. As in the second period the government raises the consumption tax, the consumption of both agents fall, which implies a negative effect on aggregate demand. By this, labor demand falls, which reduces the real wage and the marginal cost. Hence Ricardian employment and non-Ricardian consumption fall by the lower real wage. In aggregate terms, during the second period consumption, employment, inflation and output fall to levels near the steady state.

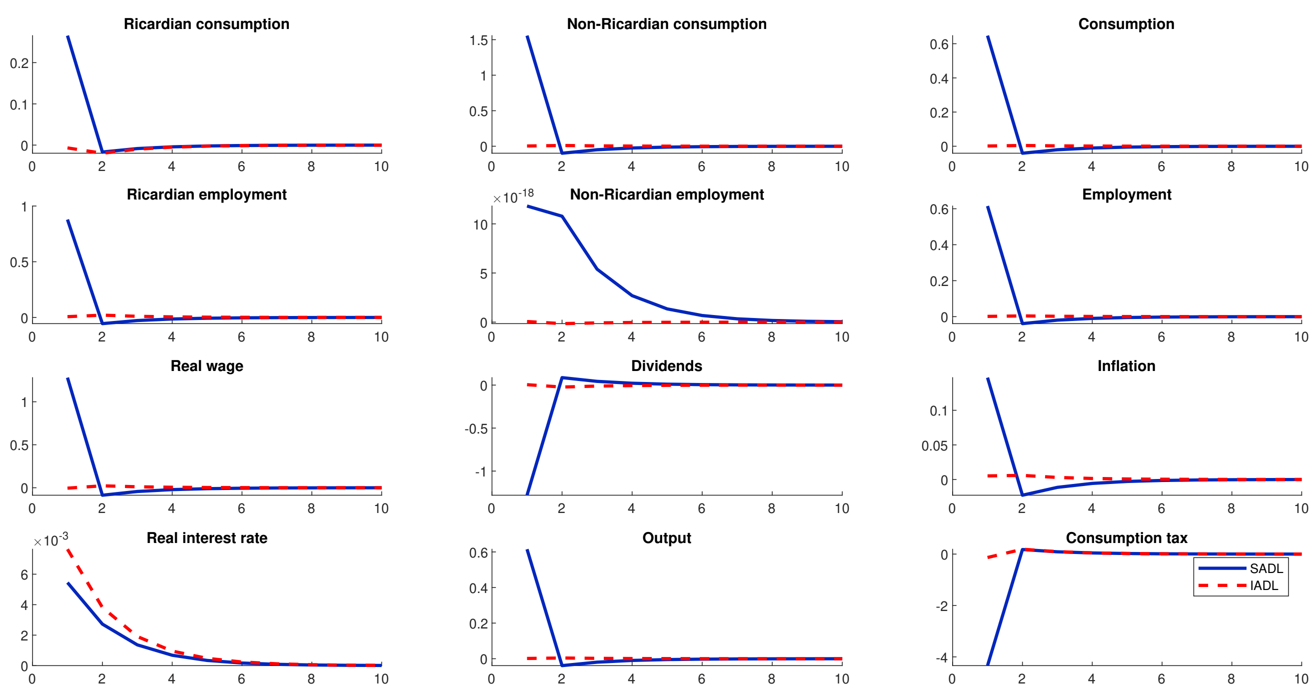


Figure 5.5. Impulse responses for a negative 1% monetary shock under the consumption tax system

As it can be seen, as with the productivity shock, the magnitudes of the effects under the SADL make it difficult to look at the dynamics under the IADL. Figure 5.6 shows a wider view of these dynamics. In this case, we know that the IADL implies a positive relationship between output and the real interest rate, as the IS curve is upward-sloping. After the shock, the real interest rate rises, which as under the SADL, makes the Ricardian households to reduce their consumption, while expecting higher taxes in the next period due to the effect of the higher real interest rate on government debt. However, in this case, given the low share of Ricardian households, this effect does not have a direct impact on aggregate consumption. As a consequence, Ricardian households supply more labor, which implies more aggregate employment and a negative effect on the real wage. Hence, from the supply side, output rises. Even though the fall in the real wage would imply less non-Ricardian consumption, as the government lowers the consumption tax rate more than the fall in consumption, non-Ricardian consumption actually rises, which implies that aggregate consumption also rises.

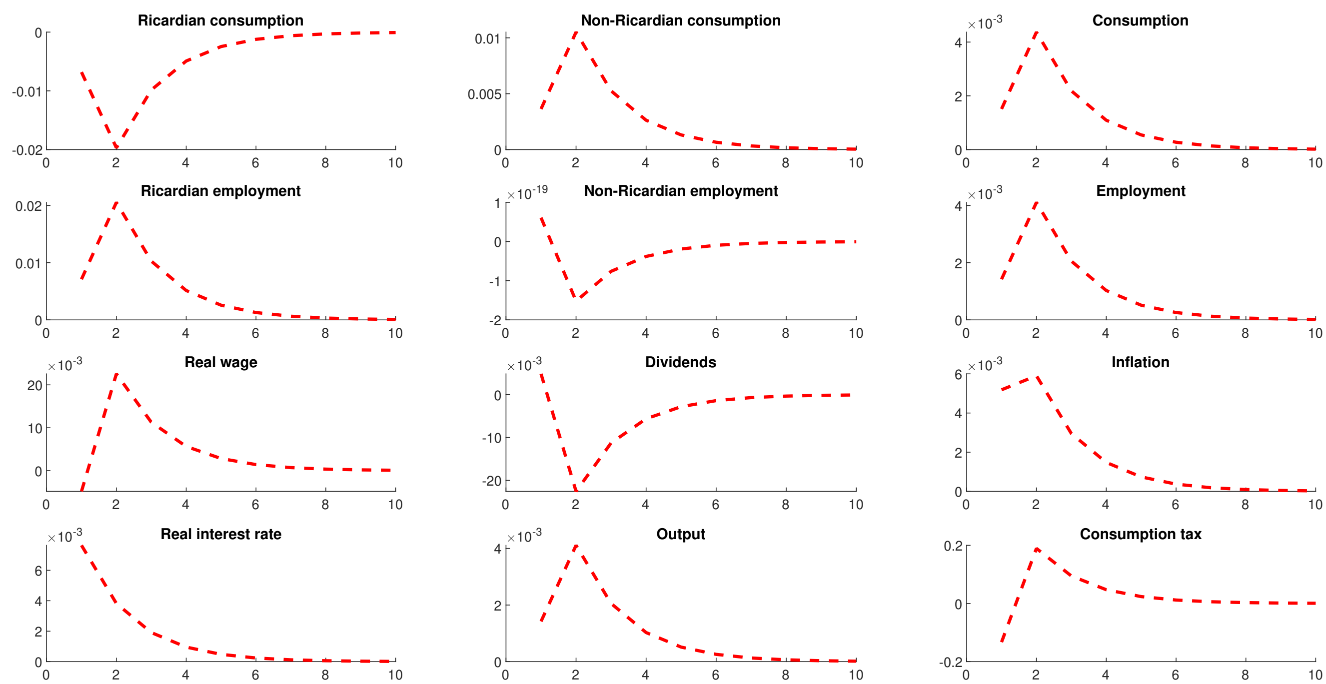


Figure 5.6. Impulse responses for a negative 1% monetary shock under the consumption tax system and the IADL

For the second period, when the government rises the consumption tax rate, Ricardian consumption falls even more, and Ricardian and aggregate employment rise again.

Nevertheless, the real wage rises due to a higher aggregate demand associated to an expected fall in the consumption tax rate in the next period. As a consequence, non-Ricardian and aggregate consumption rise again. After this period all variables start converging to the steady state.

Therefore, with a consumption tax system under the IADL, we get the positive relationship between output and the real interest rate implied by the upward-sloping IS curve. This time output rises not only immediately after the shock, but also one period after, as well as consumption and employment. This shows how different levels of asset market participation generate different results under the same tax system. Under the SADL, the consumption tax acts as an automatic stabilizer (as after the productivity shock) and we find a big effect on most of the variables immediately after the shock; while under the IADL variables are less volatile over time.

5.3 Government spending shocks

Figure 5.7 shows the impulse response functions for positive 1% government spending shock under the income tax system. Under the SADL, the government spending shock stimulates aggregate demand. By the higher aggregate demand, output increases, which raises labor demand and thus the real wage. Consequently, there is a higher marginal cost and higher inflation, by which the central bank reacts by raising the nominal rate, with a rise in the real interest rate.

As Ricardian households expect the government to raise taxes in the future, and given the higher real interest rate, they reduce their present consumption. Also, with a higher real wage and by the distortion of the expected higher income taxes, Ricardian and aggregate employment rise, while the non-Ricardian households increase their consumption. Even considering the low share of non-Ricardian households, the total effect on non-Ricardian consumption is bigger than the total effect on Ricardian consumption, which results in the rise of aggregate consumption.

During the first period, as the increase in output increases the tax base, the income tax rate falls. But for the second period, the income tax rate increases above its steady state level due to the higher real interest rate from the first period and its effect on government debt. The government spending shock ends up increasing consumption, employment, output, inflation and the real wage. Notice that under this scenario there is a positive correlation between government spending and private consumption, by the effect of non-Ricardian consumption. The positive relationship between the government spending shock is implied by the characteristic downward-sloping IS curve for the SADL.

To analyze the propagation mechanisms under the IADL after a positive government spending shock, recall that with an upward-sloping IS curve there is a negative effect of current government spending shocks on aggregate demand. With the government spending shock, Ricardian consumption falls as these households expect higher future taxes. But as this shock also has a negative effect on aggregate demand, labor demand falls, which has a negative impact on the real wage. By this, non-Ricardian consumption and Ricardian employment fall, resulting in lower levels of aggregate consumption and employment.

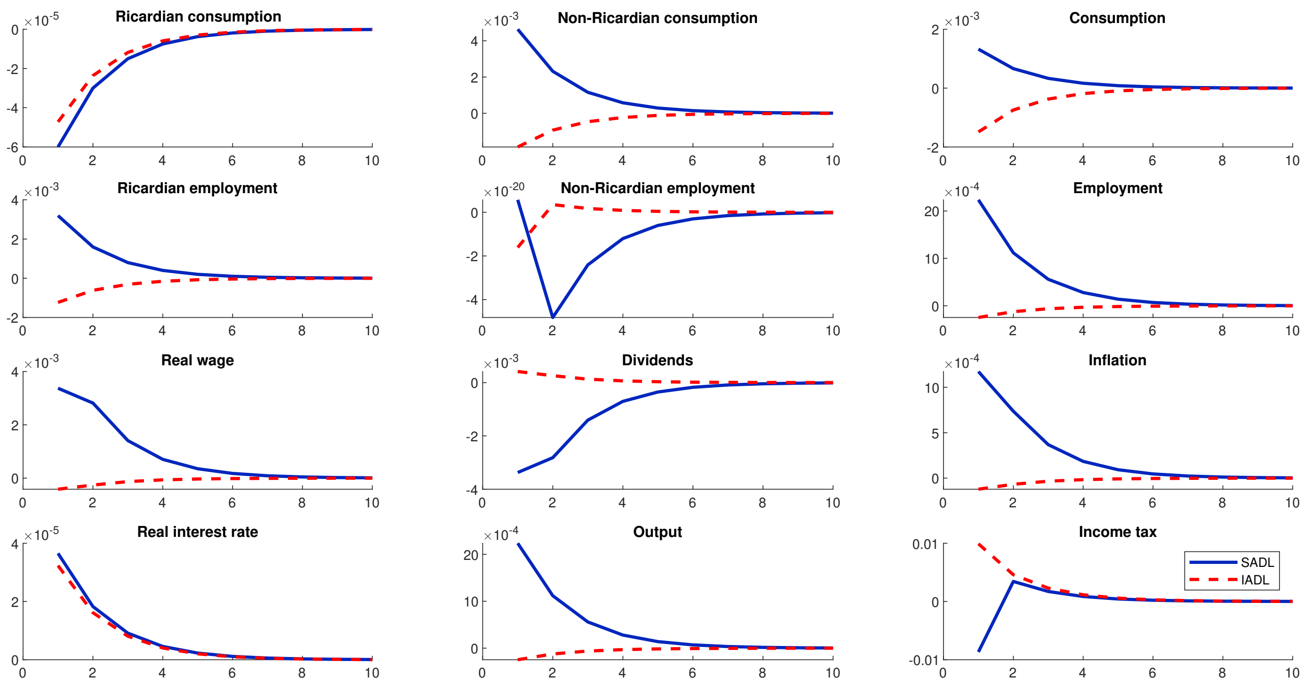


Figure 5.7. Impulse responses for a positive 1% government spending shock under the income tax system

The fall in the real wage, reduces the marginal cost, and hence inflation, and an increase in dividends. Given the passive monetary policy of the IADL case, this results in a higher real interest rate, which contributes to the fall in Ricardian consumption, as in the SADL. As the government spending shock has a negative effect on output, this reduces the tax base, which causes the income tax rate to rise from the first period. This mechanism is what Bilbiie and Straub (2004) called the non-Keynesian effects of fiscal policy, which is related to the expansionary effects of fiscal consolidation. As in the case of the monetary shock, the effect on output is very small. Therefore, the model predicts that under the given circumstances the Mexican economy would experience a very small but contractionary effect on output after an expansionary fiscal policy shock.

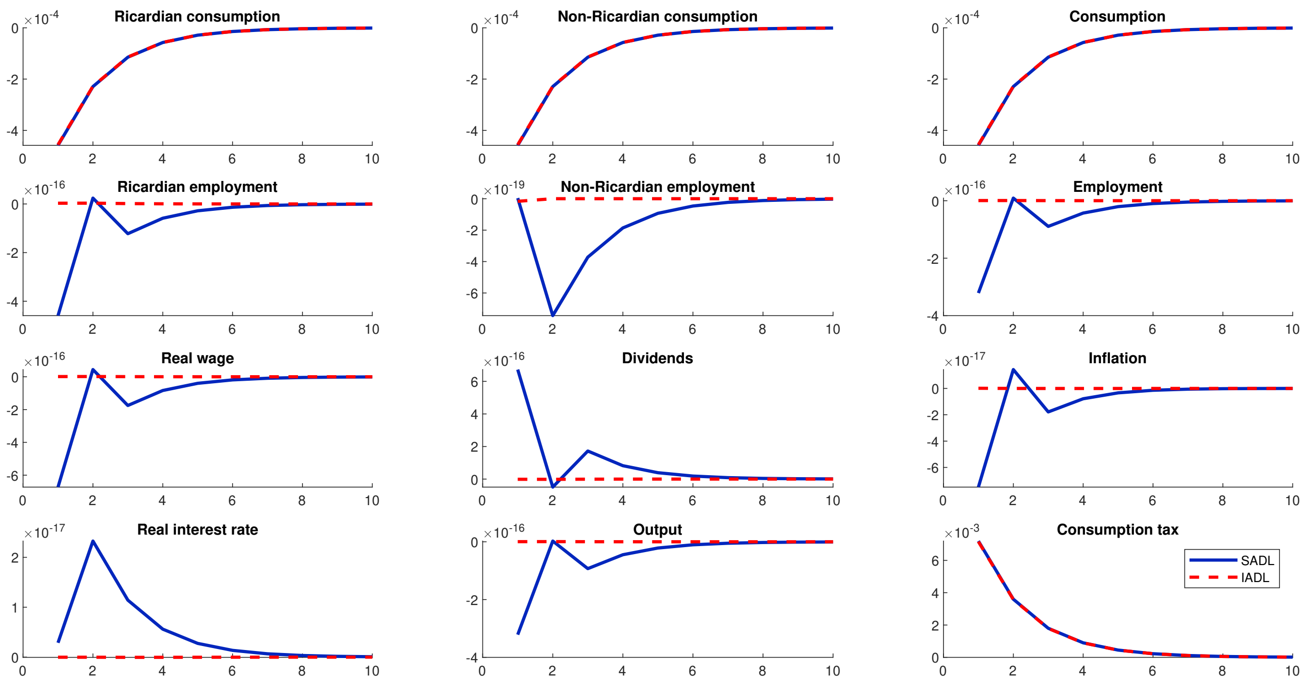


Figure 5.8. Impulse responses for a positive 1% government spending shock under the consumption tax system

Finally Figure 5.8 shows how the model reacts after a government spending shock under the consumption tax system. Note that this shock only affects the consumption of both agents and the consumption tax rate, as the effect on all of the remaining variables is practically zero. Also, a positive government spending shock has exactly the same effect under the SADL and the IADL. After the shock, the government must raise taxes from the first period to maintain the balanced budget. As a consequence, both households reduce their consumption, while the remaining variables do not change. The reason for this to happen is that the effect of government spending on aggregate demand is canceled out by the fall in aggregate consumption. Even though government spending shocks have opposite effects under the SADL and the IADL, the consumption tax plays a crucial role. See from the IS curve how the dynamics of the consumption tax rate directly affects aggregate demand, unlike the income tax, which only affects aggregate demand indirectly or by the expected bond interest tax rate, which arguably has a small effect.

The analysis of this chapter shows how after the same economic shocks an economy can react in very different manners, depending not only on the tax system that finance the government spending, but also on the share of Ricardian and non-Ricardian households. In the previous chapter we showed how monetary policy must consider the degree of asset market participation and different aspects on fiscal policy in the design of a monetary policy rule in order to achieve equilibrium determinacy. Here we showed how different levels of asset market participation have different shock transmission mechanisms for a given tax system. Hence, this provides theoretical evidence for the designing of fiscal policy.

Focusing on the effects of the different shocks on output, under the income tax system we observe that the shape of the IS curve determines the direction of the effect. Under the SADL, we find a negative effect on output after a positive productivity shock and after a negative monetary shock, while the positive government spending shock has a positive effect on output. Under the IADL we find opposite effects, as the positive productivity shock and the negative monetary shock have a positive effect on output, and the government spending shock has a negative effect. This is in line with the analysis of the IS curve from Chapter 3. By these results, the fiscal authority must consider the share of non-Ricardian households in the economy when trying to increase output through government spending. For an economy under the SADL, an expansionary fiscal policy will have a positive effect on output, but under the IADL, the government must reduce its spending to increase output.

By contrast, under the consumption tax system, we get positive effects on output after a positive productivity shock and after a negative monetary shock, while government spending shocks have no effect on output, under both, the SADL and the IADL. As we have discussed, this is due to the direct effect of the consumption tax on aggregate demand, which counteracts the effect of gevernment spending. Note that, by these results, under the consumption tax system fiscal policy is completely ineffective, which should be considered by policy makers.

Chapter 6

Conclusions

This study has analyzed the implications of introducing heterogeneous agents and distortionary taxation into an otherwise standard New-Keynesian model, with a balanced budget rule for fiscal policy and a forward-looking Taylor rule for monetary policy. Considering non-Ricardian households in the model has important consequences in terms of local dynamics and the transmission mechanism of shocks. With a sufficient level of asset market participation or high labor supply elasticity, the model follows the SADL, implying the traditional downward-sloping IS curve. However, with low levels of asset market participation or low labor supply elasticity, the IS curve is upward-sloping (IADL), which means that the real interest rate and output have a positive relationship. Consequently, for the case without government we can define a threshold for the asset market participation level as a function of the inverse of the Frisch elasticity, such that under the threshold the economy follows the SADL, and above it, the economy follows the IADL.

We have found that introducing distortionary taxation and government debt affects the asset market participation threshold. For low levels of government debt or high labor supply elasticity, the asset market participation threshold is increasing in the steady state tax rates under both, the income and consumption tax systems. Whether the effect of the income or consumption tax rate is greater than the other heavily depends on whether labor supply elasticity is below or above unit elasticity. By contrast, we found that the effect of government debt on the asset market participation threshold is very small for both tax systems.

After calibrating the model for the Mexican economy we conducted a determinacy analysis under a strict forward-looking inflation-targeting monetary policy rule. There is not a visible difference between the lump-sum taxation case and the consumption tax system. Furthermore, the income tax has a bigger impact on reducing the range of the non-Ricardian households for the IADL. Considering the SADL, the consumption tax system implies bigger determinacy regions than the income tax system, where determinacy regions are even smaller when increasing the government debt-output ratio. As a consequence, under the SADL and the consumption tax system, monetary policy can follow the Taylor principle to achieve determinacy. On the other hand, under the IADL, the income tax system seems preferable, as increasing the steady state tax rate reduces the range of non-Ricardian households for the IADL, while also heightening the upper bound of the inflation response coefficient that allows for determinacy. This implies that the income tax system allows for the monetary authority to conduct either a passive or active monetary policy, i.e., to follow the inverted or the 'standard' Taylor principle. This results also show the importance for the monetary authority to consider not only the share of non-Ricardian households in the economy when designing its monetary policy rule, but also the different features of fiscal policy.

We compared the impulse responses under the SADL and IADL after different shocks. The calibration for the Mexican economy indicated that, by the high share of non-Ricardian households, this economy follows the IADL. Furthermore, research on the monetary policy rule in Mexico implies that the central bank follows the inverted Taylor principle. This is in line with the results of the determinacy analysis, which implies that an economy under the IADL must implement a passive monetary policy in order to achieve determinacy. To compare with the impulse responses generated under the SADL, we considered a higher asset market participation under an active monetary policy rule.

Under the income tax system, the results showed the importance of asset market participation in the propagation mechanism of shocks. For the SADL and the IADL the shocks to productivity, monetary policy and government spending have opposite effects on output, depending on the shape of the IS curve. By contrast, when considering the consumption tax system we found very different results, which reinforce the remark that shifting from one system to another is far from trivial. We found that for the productivity and the monetary shocks, an economy under the SADL has bigger impacts on most of the variables, but as the consumption tax acts as an automatic stabilizer, most of the variables practically return to their steady state values one period after the shock. Also, we found that the consumption tax makes the effect of these two shocks on output to go in the same direction under the SADL and the IADL, finding a positive effect on output. As for the government spending shock, we found that it only affects the consumption of both households and the consumption tax rate, and it does so in the same magnitudes. Given the balanced budget rule, the effect of the government spending shock on aggregate demand is canceled out by the higher consumption taxes, which prevents the shock from transmitting to other variables. As a consequence, fiscal policy is inefective under the consumption tax system.

From a policy perspective, it seems desirable for Mexico, and other similar countries, to consider the heterogeneity and fiscal policy features for the design of monetary and fiscal policy. As for the two distortionary tax systems, more work needs to be done in terms of the measuring the welfare effects under the two tax systems to determine which is superior. However, certain results can be considered. Note that for the case of Mexico, and countries with a low asset market participation, the consumption tax would not act as an automatic stabilizer after productivity and monetary shocks, unless higher asset market participation is achieved. Furthermore, as we stated before, the determinacy analysis suggests that for the IADL case, the income tax seems preferable as it allows for a broader scope of action for monetary policy. Also, consider that under the consumption tax system fiscal policy is ineffective, as the consumption tax counteracts the aggregate demand effect of government spending shocks. Hence, the government would be unable to increase output through government spending. By these results, given the low asset market participation, the shift towards the income tax system in Mexico from the last years, seems preferable than the shift towards the consumption tax system that other Latin American countries have implemented. Moreover, it is important to acknowledge that there are other aspects relevant to fiscal policy designing that the model cannot consider, such as the distribution effects of both taxes.

Finally, it is important to recall that the results from the determinacy analysis depend on the parameterization and the monetary policy rule that we assumed. Future research should explore the implications of monetary policy rules different from the strict forward-looking inflation-targeting rule used in this model, e.g., exploring the effects of incorporating a positive response to output into the monetary policy rule or a current-looking rule. By a similar reasoning, implementing a fiscal policy rule different from the balanced budget rule that we assumed would generate different results for the impulse response analysis. As Giannitsarou (2007) showed in a neoclassical framework, balanced budget rules amplify business cycles, generate suboptimal volatility of tax rates and substantial welfare losses, while also having important determinacy implications. Consequently, future research should explore this question for the analysis of distortionary taxation under an heterogeneous agents framework, and as mentioned above, measure the welfare effects under both tax systems.

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List of Tables

List of Figures