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A Tinbergen Rule for Capital Taxation

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IMPRESSUM

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https://www.diw.de

ISSN electronic edition 1619-4535

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Rising Allowances, Rising Rates
- A Tinbergen Rule for Capital Taxation

Marius Clemens,* Werner Röger**

December 13, 2021

Abstract

The system of capital taxation consists of two instruments, namely a tax on profits and a depreciation allowance on investment. We will show in this paper that by acting on both instruments simultaneously it is possible to achieve both a growth and a fiscal net revenue target even in cases when a trade off prevails when each instrument is used individually. This is an application of the Tinbergen rule (Tinbergen 1952) to capital taxation. In the current context a fundamental requirement for this rule to work is that the two tax instruments imply different trade offs.

As will be shown in the paper, depreciation allowances have a more favorable trade off between growth and net revenue in the long run compared to statutory profit tax rates. Thus, by increasing depreciation allowances and the statutory tax rate at the same time it is possible to both increase growth and fiscal space.

In a model simulation calibrated to the German economy and tax system an increase of the tax depreciation rate for all investments from 10% to 25% leads to more than 2 percent GDP increase and more than 6 percent higher private investments in total. Whereas GDP and investment rise steadily over time, the government budget becomes negative in the short run. In the long run the sign of the fiscal budget effect is determined by the assumption about indexation of government consumption to GDP. However, according to the Tinbergen rule for capital taxation slight adjustments of the capital tax rate could balance out these deficits and generate additional fiscal space.

JEL: E61, E62, H25

Keywords: Fiscal Policy, Capital Allowance, Capital Tax

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1 Introduction

Many studies analyze the macroeconomic impact of capital tax reforms on investment and government revenues or more specifically the degree of self-financing. While the direction of the impact of capital taxes on investment are unambiguous for the standard model of investment the degree of self-financing of specific measures is less clear. In the academic literature this question is closely related to the Laffer curve which measures the relationship between the tax rate and tax revenues. Studies of the Laffer curve suggest that the rate of self-financing increases with the level of the tax rate: Trabandt and Uhlig (2011) find that the capital tax rates in most industrialized countries are on the left side of the Laffer curve, i. e they are below the self-financing level. This is even more true today given various tax reforms which have taken place in the meantime in some countries. This leaves the question which fiscal measures should accompany capital tax reductions in order to meet government deficit/debt targets.

Often (at least in macroeconomic studies, See Lieberknecht and Wieland (2019)) the tax system is summarized by the effective tax rate which adjusts the statutory capital tax rate for depreciation allowances received by the firm.[1] This reduces the capital tax system to one dimension, namely a tax on profits. A recent fundamental tax reform, namely the Tax Cuts and Jobs Act (TCJA-17) in the US from 2017, which consisted in a permanent reduction of the corporate tax rate as well as a temporary increase in depreciation allowances has been studied intensively. The paper by Lieberknecht and Wieland (2019) shows that this reform is likely to have positive GDP effects but fails to be self financing. This is in line with a large number of both academic papers (e.g. Barro and Furman (2018), Penn Wharton Budget Model (2017)) and reports written by government institutions (e.g. Council of Economic Advisors Joint Committee on Taxation 2017 (2017), Council of Economic Advisors Joint Committee on Taxation 2017 (2018)). Gale et al. (2017) provide a review of various studies. All studies show positive GDP effects, however, within a wide margin, ranging from 0.1 to 2.9% after 10 years. In a recent paper Furno (2021) assesses TCJA-17 using a model which distinguishes between the corporate tax rate and depreciation allowances and argues that because of an already highly accelerated tax depreciation rate (48%), US corporate taxes have not been very distortionary and finds that the multiplier of the tax cut in the US has been smaller than one. A recent study by Dorn et al. (2021) for Germany also looks at both elements of capital taxes separately and compares their economic and budgetary impact. The paper concludes that especially the latter measure has good self-financing properties in the long run, compared to the reduction of corporate taxes.

In our paper we systematically explore the trade off between growth and self-financing properties of permanent changes in profit taxes and depreciation allowances. We will show that the (long run) self-financing property of increasing tax allowances is not robust to assumptions on labor supply and the degree of indexation of government expenditure to GDP. However, the growth vs. self-financing trade off remains relatively more favourable in case

[1] A depreciation allowance, also known as capital allowance, allows tax payers to get tax relief on their capital expenditure by allowing it to be deducted from the tax base. Usually, capital allowances will be incurred on investments, with the deduction available normally spread over many years. Thus, in order to reform the capital tax, besides statutory tax rate changes the government could also change the speed at which investments can be deducted.

of further accelerating depreciation. Using this feature, we show that by acting on both capital tax instruments simultaneously it is possible to achieve both a growth and a net revenue target even in cases when a trade off prevails for each instrument individually. This is an application of the Tinbergen rule (See Tinbergen (1952)) to capital taxation.

However, the short and medium run trade off in case of depreciation allowances is less favorable compared to the long run. Therefore, if governments are constrained by debt limits (e.g. a debt brake) in the short run this makes it necessary to look at the choice of these two instruments not only from a long run perspective. Therefore, we consider various scenarios and show the time path of growth and deficits.

The baseline for our analysis are capital tax parameters characterising the German capital tax system, with a profit tax rate[2] of 30% and a tax deprecation rate of 10%. The latter is substantially lower than the US rate. Similar to Furno (2021) we also find that corporate taxes become less distortionary as tax depreciation increases and we explore the growth-net revenue frontier for depreciation rates in the range between 10% and 100%.

2 A Model with Depreciation Allowances

We apply a reduced model framework of Clemens and Roeger (2021).[3] We consider two infinitely living household types which differ with respect to their savings behavior. Unrestricted households, also known as Ricardian households, have full access to financial markets, liquidity-constrained households, also known as hand-to-mouth consumers, consume their current period income. Both types buy durable and non-durable consumption goods produced by two different sectors. We further assume that capital and labor is sector specific. There is a monopolistically competitive retail branch in each sector which sells goods produced in the respective sector to households. In the following we only describe the specific model extensions.[4]

2.1 Investment Decision of the Firm

Consider a firm which is subject to the following intertemporal profit maximization problem:

$$V_t = \sum_{s=t}^{\infty} \prod_{j=0}^{s-t} \left(\frac{1}{1+r_j} \right) \left[(1-\tau_s^C)[Y_s - w_s L_s] - P_s^I I_s \left(1 + \gamma_K \left(\frac{I_t}{K_{t-1}} - \delta \right) \right) + P_s^I I_s NPV_s^A \right], \tag{1}$$

with Y_s denotes output, w_s real wage, N_s labor volume, P_s^I the investment price deflator, and I_s private investment. $\left(\frac{I_t}{K_{t-1}} - \delta \right)$ are the capital adjustment costs and γ_K measures the importance of capital adjustment costs to the firms investment decision. We consider two important tax variables, the statutory profit tax τ_t^C and the net present value of depreciation allowances NPV_t^A. For any Euro of investment undertaken in t the firm can deduct depreciation allowances in current and future periods. The total deduction is summarized by the NPV of current

[2] We do not distinguish between different legal type of corporations or different local authorities. Thus, the profit tax combines German corporate tax 'Körperschaftsteuer', occupation tax 'Gewerbesteuer', and parts of the personal income tax 'veranlagte Einkommensteuer'.

[3] We do not consider specific VAT channels, sectoral differences and keep the household side as simple as possible. Instead, we concentrate on the implementation of depreciation allowances and the optimal firm decision.

[4] The complete model equations can be found in Appendix 5.3.

and future depreciation allowances. The basis for the allowances in each period is always the remaining value of the investment undertaken in t, i.e. the remaining value after depreciation multiplied by the price of the investment good in the corresponding period. The present discounted value of depreciation allowances from an investment project undertaken in (current) period t is

$$NPV_t^A = \sum_{s=t}^{\infty} \prod_{j=0}^{s-t} \left(\frac{(1+\pi^I_{s+j+1})(1-\delta^{TAX}_{s+j})}{1+r_{s+j}} \right) \tau^C_s \delta^{TAX}_s, \tag{2}$$

with δ_t^{TAX}, denoting the percentage share of the investment value is tax deductible. Thus, δ_t^{TAX} is the depreciation rate for tax purposes, it is not necessarily identical to the actual technical depreciation δ. In practice the tax depreciation scheme for investment goods is often degressive and the tax depreciation rate a constant $\delta_t^{TAX} = \overline{\delta}^{TAX}$. Similarly, the profit tax rate in many countries is a constant rate $\tau_t^C = \overline{\tau}^C$. Deriving the first order conditions of the firm's investment problem yields:

$$V'(K_t) = (1-\tau_t^C)Y'(K_t) - \lambda_t + \lambda_{t+1}(1-\delta)(1+r_t)^{-1} = 0 \tag{3}$$

$$V'(I_t) = -P_t^I \left(1 + \left(\frac{I_t}{K_{t-1}} - \delta\right) - NPV_t^A\right) + \lambda_t = 0. \tag{4}$$

Combining the equations (3) and (4) we get the optimality condition for firms capital demand:[5]

$$Y'(K_t)(1-\tau^C) = P_t^I\left(1+\gamma_K \frac{I_t}{K_{t-1}}\right) - P_{t+1}^I\left(1+\gamma_K\frac{I_{t+1}}{K_t}\right)\left(\frac{1-\delta}{1+r}\right) - \left(P_t^I NPV_t^A - P_{t+1}^I NPV_{t+1}^A \frac{1-\delta}{1+r_t}\right), \tag{5}$$

For discussing the intuition of the equation we simply assume adjustment costs of $\gamma_K = 0$. Then optimal investment demand (5) reduces to

$$MCoC = Y'(K_t) = (r_t+\delta)\frac{\left(1 - \frac{\tau^C \delta^{TAX}}{1-\frac{1-\delta^{TAX}}{1+r_t}}\right)}{1-\tau^C}, \tag{6}$$

which equates the marginal product of capital with capital cost. Capital cost is a product of the required gross return and a tax term which summarizes how τ^C and δ^{TAX} affect capital cost for the firm. As shown by this formula an increase in the profit tax rate has two effects. Without depreciation allowances an increase in τ^C unambiguously increases capital cost. The presence of depreciation allowances mitigates this effect since higher profit taxes also increase depreciation allowances. An increase in δ^{TAX} reduces capital cost for firms and stimulates investment. Thus, the government can stimulate private investment by reducing the depreciation rate for tax purposes without changing the profit tax rate.

[5]Note that P^I is defined as relative investment price $\frac{P^INV}{P^Y}$. Therefore, the relative investment price inflation can be expressed as $\pi^I = \pi^{INV} - \pi^Y$.

2.2 Implications for the Government Budget

The individual firm makes investment decisions based on the expected value of depreciation allowances the firm can collect over the (taxable) lifetime of the investment. The government in turn pays each period investment allowances from all investments undertaken in the past. Depreciation allowances A_t paid by the government in period t are given by

$$A_t = \sum_{i=0}^{\infty} (\delta_{t-j}^{TAX})^i \tau_{t-i}^C (1 - \delta_{t-i}^{TAX}) P_{t-i}^I I_{t-i}. \tag{7}$$

The government pays depreciation allowances on the surviving value of all past investments. It is noteworthy that spending on depreciation allowances do not depend on δ^{TAX} in the long run (steady state), since the government only changes the period over which the investment good depreciates:

$$\overline{A} = \frac{\overline{\delta}^{TAX} \overline{\tau}^C}{1 - (1 - \overline{\delta}^{TAX})} \overline{P}^I \overline{I} = \tau^C \overline{P}^I \overline{I}. \tag{8}$$

An increase in depreciation allowances does, however, increase spending on allowances in the short run. Thus, increasing depreciation allowances will increase government spending in the long run only to the extent in which investment goes up. This is different to a reduction of the statutory corporate tax rate which reduces government revenue if investment would stay the same. It can therefore be expected that an increase in depreciation allowances combined with an increase in the profit tax revenue yields positive net revenues which can be used for redistribution.

In order to focus on the fiscal space used for redistribution, we simply assume that the government follows a lump-sum rule, where all surplus or deficits in period t transferred or taxed immediately to the households:

$$T_t = \tau^C (Y_t - w_t L_t) + \tau^{vat} c_t + \tau^w w_t L_t - A_t - r_{t-1} B_{t-1} - g_t^C - g_t^I \tag{9}$$

The lump-sum value T_t acts as measure for fiscal space which can be generated by a government through a change of the capital tax system vis-a-vis the combination of corporate tax and depreciation allowance. We are not interested how to spend the additional fiscal space, but rather which combination of corporate tax and depreciation allowance yields the highest additional fiscal space for a redistribution policy.

2.3 Calibration

The empirical validation of our model is provided by setting parameters such that the model steady state fits empirical observations for the economy and the tax system in Germany between 1995 and 2019. The structural empirical values and the calibration for Germany are summarized in Table 3 and 4 in the Appendix 5.1.

We assume a log-utility function in consumption and set the inverse of the intertemporal substitution elasticity σ equal to one. The time preference factor β is set to 0.996 to match a steady-state real interest rate of 1.6 percent. With a capital share of $\alpha = 0.325$ we can match the capital-to-output ratio of closed to 3. The parameter that determines the inverse Frisch elasticity of total labor volume ρ is set to 0.5 and the share of liquidity-constraint households n is 0.28 according to Grabka and Halbmeier (2019). The quarterly depreciation rate for private investments δ^j is calibrated to 0.014. For the durables we assume $\delta^d = 0.025$ in order to consider slightly higher annual depreciation rates of durable goods such as cars. The steady state ratio of government consumption per GDP $\overline{g}/\overline{y}$ is calibrated to 19 percent according to the observed average value. The durable consumption per GDP ratio is set according to its empirical counterpart of 0.11.

Capital, price and wage adjustment costs are set to $\gamma^K = 20$, $\gamma^P = 20$ and $\gamma^W = 120$, the latter corresponds to Calvo Parameters of 0.76 and 0.92, and are set closed to values found in the literature.[6] Finally, the adjustment cost parameters for private investments and durable consumption are set to $\gamma^I = 15$ and $\gamma^D = 3$. The substitution elasticity between durable and non-durable goods is set to 0.75.

Monetary and fiscal policy parameters are set mainly according to the literature. For the monetary policy rule we assume central bank weights for interest rate smoothing of $\phi^i = 0.9$, for the CPI inflation target $\phi^\pi = 1.5$ and for the output gap target ϕ^y and for the output growth target ϕ^{dy} both to zero. By the latter we consider that the central bank does not counteract fiscal policy effects. In the fiscal sector, we calibrate the steady state government debt-to-GDP ratio $\overline{b}/\overline{y}$ equal to 60% on an annual basis. The steady state tax rates $\overline{\tau}^{vat}$, $\overline{\tau}^C$, $\overline{\tau}^W$ are set equal to their empirically observed values in table 3. The remaining component of the fiscal budget $\overline{T}$, in the subsequent analysis defined as fiscal net revenues or fiscal space, can be calculated as a difference between revenues and expenditures.

3 Results

The main focus of the paper is to analyze to what extent the combination of profit tax[7] and depreciation allowance is able to increase investment and fiscal space at the same time. In order to answer this question we start with a short explanation of the Tinbergen rule for capital taxation.

3.1 A Tinbergen Rule for Capital Taxation

The application of the Tinbergen rule in our context of capital taxation can be illustrated as follows. Suppose a government wants to maximise a welfare function with income Y and redistribution as targets and redistribution is achieved via a fiscal surplus, which can be used for increasing transfers T. We further assume that the welfare function is concave w.r.t. these two arguments

$$\mathbb{W}(Y,T) = \log(Y) + \omega \log(T) \tag{10}$$

Where ω denotes the relative weight the government is attaching to these targets. From 10 we obtain

$$\frac{\partial T}{\partial Y} = -\frac{T}{\omega Y} \tag{11}$$

Which shows that the indifference curves are downward sloped and convex. The policy problem can now be illustrated by Figure 1. The government has the profit tax rate and depreciation allowances at its disposal. The

[6] See e.g. Burgert et al. (2020).

[7] Note, we neither consider different legal types of corporations nor different local authorities. Therefore, the profit tax rate subsumes German corporate taxes ('Körperschaftsteuer'), occupational taxes ('Gewerbesteuer') and parts of the personal income taxes ('veranlagte Einkommensteuer').

blue line shows feasible long run combinations of Y and T which can be realised by changing τ^C and the red line shows the relationship between these two variables for changes in δ^{TAX} as implied by our parameterization. The figure shows that changing depreciation allowances leads to a more favourable growth - net revenue trade off compared to changing the statutory profit tax rate. The slope of the indifference curve depends crucially on the preference for redistribution ω. For a small/high value of ω the indifference is steep/flat. We first consider the case for a government with low ω (Figure 1a). Point A in 1 shows the baseline for growth and net revenue (which may have been an optimal point for an outgoing government). Given the trade-offs implied by the τ^C and δ^{TAX} locus, the government knows that by increasing δ^{TAX} or lowering τ^C it can move the economy in a south east direction and it also knows that the trade offs of both instruments are different, in particular the growth revenue (loss) trade off is more favourable for δ^{TAX} than for τ^C.

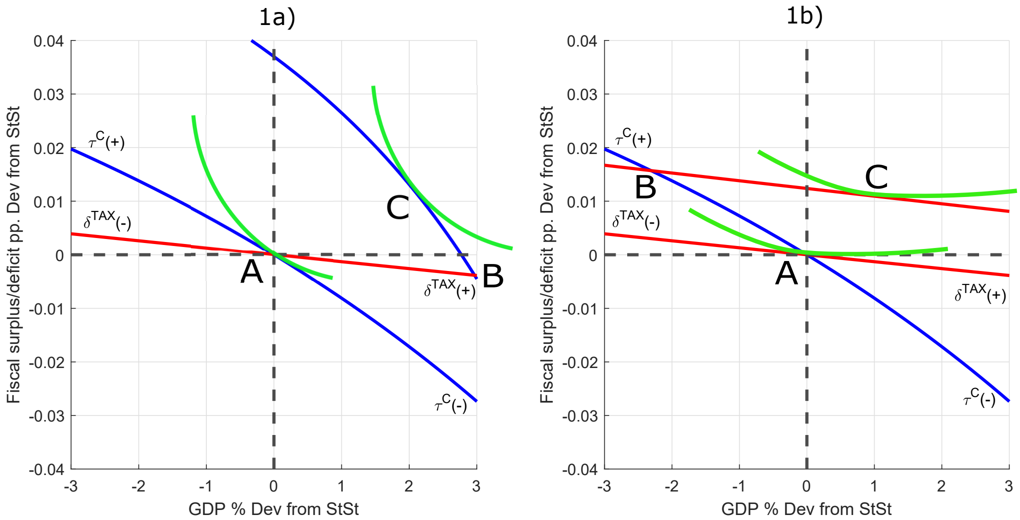

Figure 1: Tinbergen rule for capital taxation

As can be seen, given preferences, by increasing δ^{TAX} the government can move to higher level of utility (point B) but it cannot avoid the trade off (higher growth and lower revenues). The government would exclude lowering τ^C, because this would imply a welfare loss. However, by appropriately adjusting both instruments, namely increasing δ^{TAX} and increasing τ^C simultaneously it can further increase the level of welfare beyond point B, by moving the economy to point C.

Alternatively a government favouring redistribution (Figure 1b) could improve the level of welfare by increasing τ^C, while lowering δ^{TAX} would be unattractive. Like in the previous case it cannot avoid the trade off between growth and redistribution by just using one instrument. However, the trade off can be avoided and a higher welfare level can be reached by complementing the increase of τ^C by increasing δ^{TAX}.

This can be regarded as an application of the Tinbergen rule for a growth friendly and a redistribution friendly government respectively. As can be seen from the figure, an essential requirement for these joint policies to work is the presence of different trade offs implied by the two instruments. Without this difference, policy cannot avoid the trade off, while in case of different trade offs, the instruments span a two dimensional space of the two targets and policy has the option of realising a specific point within this space.[8]

3.2 Permanent Depreciation Allowance Shock

In order to analyze our theoretical implications in more detail but also to quantify the macroeconomic effects of different tax reforms we focus on a model application. Therefore, in a first step, we increase only the tax deductibility from 10 years to 4.5 years, by simulating a permanent depreciation allowance shock that increases δ^{TAX} from 0.025 to 0.07 which corresponds to an annualized change from 10% to 25%. We assume, that the debt to GDP ratio remains unchanged in order to measure the consequences of the shock to government net revenues. As explained above, positive net revenues are used for increased transfers. This illustrates the direct consequences of fiscal space that can be used for redistribution policy, e.g. towards low income groups.

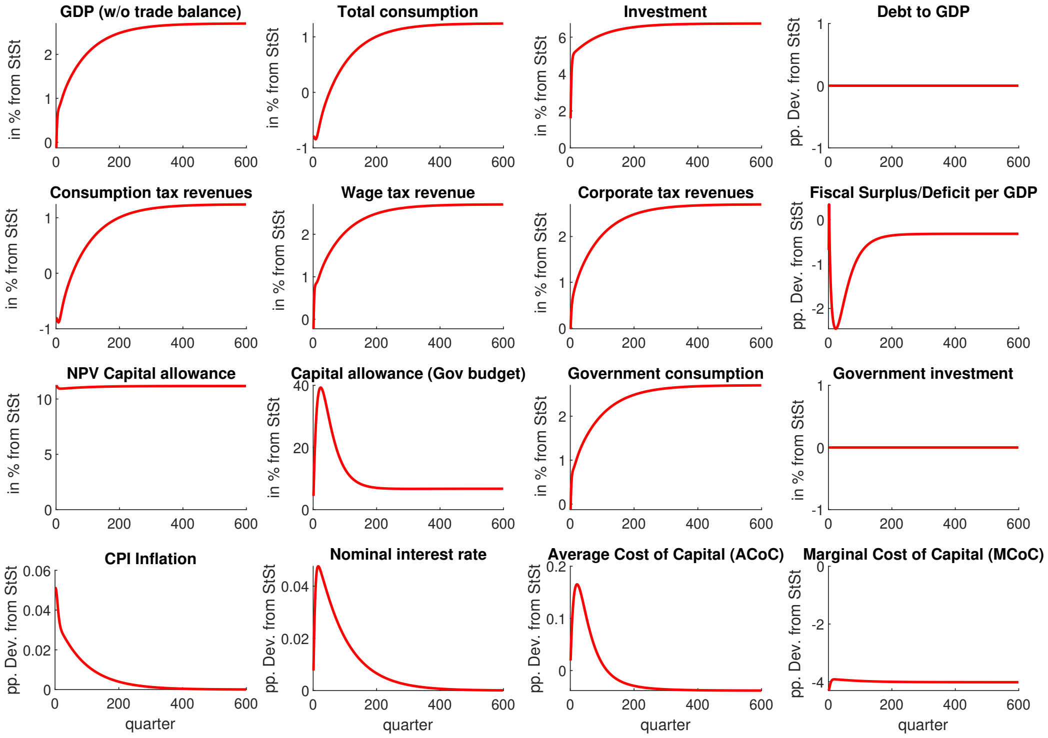

Figure 2: Impulse Response Functions: Permanent depreciation allowance shock (δ^{TAX} from 2.5% to 7% or 10% to 25% annualized)

As can be seen in Figure 2 increasing the tax depreciation rate δ^{TAX} permanently leads to an increase of GDP by 2.5 percent in the long run which is accompanied by an increase of private investments of about 6 percent and an increase of total consumption of 1 percent. This translates into higher tax revenue from corporate profits, wages, and consumption. However, there are also additional expenditures: First, although the raising tax

[8]The non-linear relationship between the two instruments and their economic and fiscal effects can alternatively visualized via Laffer curves. See Figure 5 in Appendix 5.2 for different economies and tax systems.

depreciation rate does not affect the long run depreciation allowances directly, it stimulates higher permanent investments, which results in higher permanent depreciation allowance expenditures. Second, a raising GDP in combination with the assumption of a constant debt to GDP ratio results in higher debt level. Therefore, public interest payments increase. Third, if we further assume that the public consumption and investment share stays constant over time, government spending raises with GDP. Summarizing a permanent increase of the tax deductibility of investments raises GDP, consumption and investments but the fiscal balance becomes negative (fiscal deficit), the fiscal space shrinks.

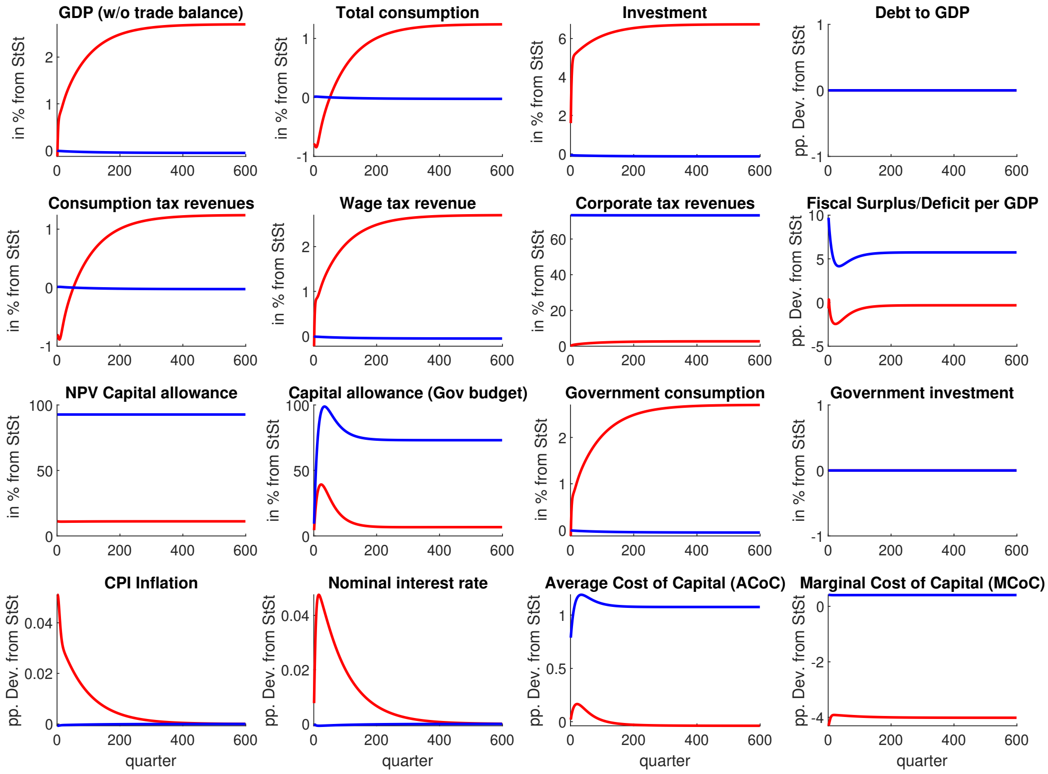

Figure 3: Impulse Response Functions: 'Growth-neutral' combination of permanent depreciation allowance shock and corporate tax shock (δ^{TAX} from annualized 10% to 15% & τ^C from 30% to 52%)

3.3 Additional 'Growth-neutral' Permanent Profit Tax Rate Shock

An increase of the profit tax rate would decrease GDP and investment but would increase the fiscal revenues. Therefore, in a second step we construct a 'growth-neutral' combination of depreciation allowance and profit tax change. Given the growth effects from step 1, we generate a profit tax rate change which is determined by the condition that GDP does not deviate from the baseline level in the long run. Figure 3 illustrates that this combination of tax depreciation rate δ^{TAX} and an increase of the profit tax to 52 percent (+ 22 pp) is indeed neutral to economic growth. GDP, consumption, investment and wages stay constant permanently. However, fiscal net revenues per GDP become positive and increase by 5.7 percentage points, such that the government has a fiscal surplus. Given the positive association between tax increases and government revenue this increase of T gives the maximum fiscal space (conditional on the magnitude of the increase of depreciation allowances in step 1) for redistribution which is possible without a (long run) loss of GDP.

We could interpret step 1 and step 2 as two polar cases: If only step 1 is executed, the increase in tax deductibility reaches the maximum GDP effect (but with a fiscal deficit).[9] In step 2 the increase of depreciation allowances reaches the maximum fiscal surplus (but with zero growth compared to the baseline).

3.4 Efficiency of the Tax Reform

Step 1 and step 2 show the trade-off between δ^{TAX} and τ^C. A possible way of interpreting the results of the proposed tax reform is to compare the marginal increase in capital cost implied by the proposed tax reform to the change in the effective/average tax rate for corporations. Assuming that the tax reform leaves r_t, π_t^Y and P_t^I unchanged, then the marginal increase of capital cost can be derived as total differential from equation (6) and is given by:

$$\Delta MCoC_t = \frac{\partial MCoC}{\partial \tau^C} \Delta \tau_t^C + \frac{\partial MCoC}{\partial \delta^{TAX}} \Delta \delta_t^{TAX} \tag{12}$$

with $\frac{\partial MCoC}{\partial \tau^C} > 0$, $\frac{\partial MCoC}{\partial \delta^{TAX}} < 0$, $\Delta\delta^{TAX} > 0$ and $\Delta\tau^C > 0$. Note, the direction of this change is relevant for the investment decision. We define the average cost of capital as

$$CoC_t = \frac{\tau^C (Y_t - w_t N_t) + A_t}{K_t} \tag{13}$$

And the change in the average cost of capital yields change of capital tax revenue, by keeping the tax base constant.

$$\Delta CoC_t = \frac{\Delta\tau^C (Y_t - w_t N_t) + \Delta A_t}{K_t} \tag{14}$$

An increase in the efficiency of the capital tax system is indicated by a tax reform which yields $\Delta MCoC_t \leq 0$ and $\Delta CoC_t \geq 0$, with strict inequality holding for at least one component. Thus, e.g. for $\Delta\delta^{TAX} = 0.045$ and $\Delta\tau^C = 0.05$ and efficiency improvement of the capital tax system can be achieved.

Figure 4 fully illustrates the profit tax policy trade offs. On the left hand side we show the simulated additional GDP and fiscal revenues for different combinations of profit tax rates and capital allowance rates if the capital allowance rate changes compared to the steady state ($\Delta^{TAX} = 0$). The whole Figure can be split in four quadrants: In the left upper quadrant combinations of profit tax rates and the capital allowance will lead to higher fiscal revenues but GDP losses. The right upper quadrant shows those combinations leading to higher GDP and fiscal revenues compared to the initial situation (steady state with capital allowance of $\delta^{TAX} = 0.025$). In the left lower quadrant, the capital tax system reform will lead to lower GDP and lower fiscal space, while in the right lower quadrant GDP increases but the reform is not self-financing.

[9] Theoretically, the maximum GDP can be reached by introducing immediate depreciation allowances by setting $\delta^{TAX} = 1$. In this case GDP increases by 4.5 percent, investment by 11 percent compared to the steady state. But still at the costs of loosening fiscal space. See Table 2 for a comparison of different tax depreciation rates.

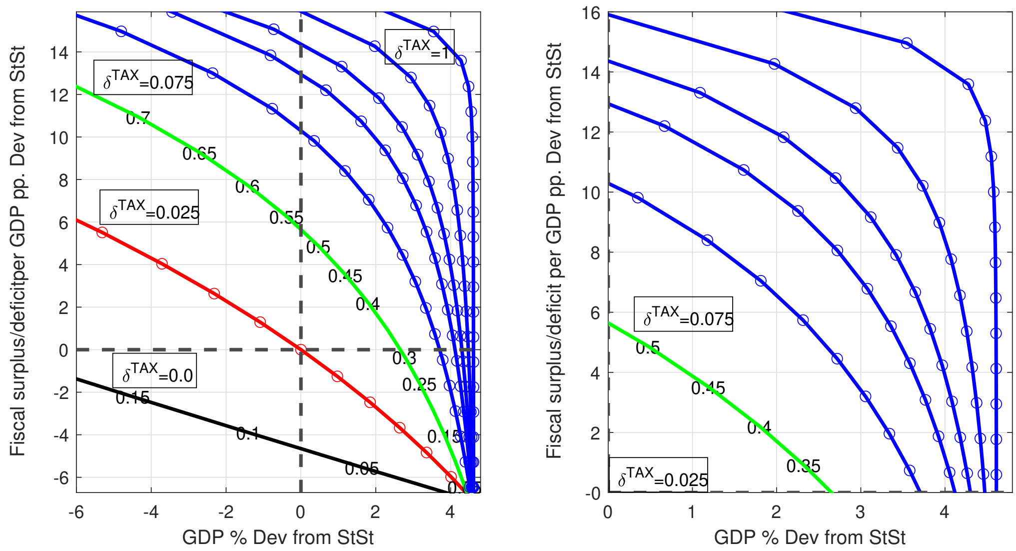

Figure 4: Trade off between growth and fiscal revenues

The origin captures the baseline where the profit tax is at 30% and neither GDP nor fiscal revenues change. The red line reports baseline values for depreciation allowances ($\delta^{TAX} = 0.025$) and the effects of a changing profit tax rate to GDP and fiscal revenues. A decrease of the profit tax from 30% to 25% will increase GDP but reduce fiscal revenues. An increase of the profit tax rate leads to higher revenues but lower GDP. The lower black line describes what would happen to GDP and fiscal space if we - in addition to profit tax changes - eliminate capital allowances ($\delta^{TAX} = 0$). If we reduce the profit tax to τ^C=0 (from 0.3 in steady state), GDP will be higher by 1.4%, but the whole tax reform is still not self-financing. Therefore, fiscal space diminishes, and redistribution measures have to be cut. However, the capital allowance elimination can not be compensated by the profit tax cut: with smaller profit tax cuts the government could still create additional space for redistribution policy, but GDP will become smaller. The green line denotes the case when capital allowances increase to $\delta^{TAX} = 0.07$, annually to 25%. Again, profit tax reductions increase the GDP level. Corporate tax increases depicted by the green line limited through the zero y-axis, lead to both, higher GDP, and fiscal revenues. Further increases of the capital allowance rate up to 100% will create even more fiscal space, as can be seen by the blue lines ($\delta^{TAX} = 0.07$,...$\delta^{TAX} = 1$).

The upper-right quadrant incorporates all efficient combinations and is enlarged on the right hand side in Figure 4. Here, the trade off between efficient reforms, i.e. combinations of profit tax rate and depreciation rate adjustments that increase GDP and net revenues, becomes more distinct. From Figure 4 it can easily shown that by increasing δ^{TAX} the trade off between increasing both tax parameters becomes increasingly favorable, because with rising depreciation allowances the profit tax rate becomes less distortionary and negative growth effects only appear for extreme values of the profit tax rate.[10]

[10]Since capital adjustment costs are not subject to depreciation allowances the profit tax does not become completely non distortionary and becomes large as the profit tax approaches 100 per cent.

3.5 Transitory Dynamics

In the next step, we want to analyze how the trade off changes during short- and medium-term (See table 1). In the case of the depreciation allowance shock (+15% annualized) GDP and investment rise steadily over time, but the government budget becomes negative in the short and medium run. If total private investments are tax deductible, GDP and private investments increase by 0.5 and 4.0 percent in the first year compared to the initial values ('Only Depreciation Allowance Shock' scenario). This generates a fiscal deficit of 0.3 percent of the GDP. Over the medium term, measured via a 5-year average, GDP and private investment increase by 1.0 percent and 5 percent compared to the initial values. The fiscal deficit increases up to 1.5 percent of the GDP. Thus, in this baseline scenario the short and medium run trade off in case of depreciation allowances is less favorable compared to the long run.

Table 1: Transitory Dynamics

Scenario	GDP (in %)[1]	Investment (in %)[1]	Fiscal Surplus/GDP (in pp)[1,2]
Short-Term			
'Only Dep. Allowance Shock'	0.5	4.0	-0.3
'Combined Tax Change GR'	0.5	3.6	0.8
Medium-Term			
'Only Dep. Allowance Shock'	1.0	5.2	-1.5
'Combined Tax Change GR'	0.9	4.7	-0.6
Long-Term (steady-state)			
'Only Dep. Allowance Shock'	2.7	6.7	-0.4
'Combined Tax Change GR'	2.5	6.2	0.3

[1] % or pp Deviation from initial values. Short-Term: 1 Year, Medium-Term: 5 Years, Long-term: Steady-State.
[2] Annual Average.
Notation: 'Only Dep. Allowance Shock': $\delta^{TAX} = 25\%$, 'Combined Tax Change GR': Growth + Fiscal Revenues - $\delta^{TAX} = 25\%$, $\tau^{C} = 32.5\%$.

Since governments are constrained by debt limits (e.g. a debt brake) in the short run it makes even more necessary to look at the choice of these two instruments not only from a long run perspective. If we consider the combination of a higher tax depreciation rate (+15% to 25% annualized) and a slightly higher tax rate (+2.5% to 32.5%), we find positive budget effects in the short- but not in the medium-run ('Combined Tax Change' scenario). Thus, the different angle of the trade off considers a specific tax rate pattern over time which balances the fiscal budget. For example, in the short- and the long-term a capital tax rate smaller than 32.5% is possible in order to achieve budget-neutrality of the increasing tax depreciation rate, while in the medium-term the capital tax rate has to be higher than 34%.

3.6 Robustness

In this section we test the robustness of our results for further specific model scenarios. The following table summarizes our robustness exercise. In the first three rows, we present percentage change of GDP, investment and percent point change of the fiscal surplus per GDP for the three different experiments: the reduction of the tax depreciation rate, the 'growth-neutral' experiment with a combination of tax depreciation reduction and a maximum profit tax rate increase, and a combination of both instruments which lead to higher GDP and fiscal revenues. An 'immediate tax depreciation', i.e. a 100% tax deductibility of investment leads to almost doubling of GDP and government expenditure compared to the baseline result.

Table 2: Robustness - Long-term (Steady-state) Effects

Scenarios	GDP (in %)[1]	Investment (in %)[1]	Fiscal Surplus/GDP (in pp)[1]
'Only Dep. Allowance Shock'	2.7	6.7	-0.4
'Combined Tax Change GN'	0.0	0.0	5.7
'Combined Tax Change GR'	2.5	6.2	0.3
'Immediate Depreciation'	4.5	11.1	-0.5
'Constant Gov Consumption'	2.2	6.3	0.2

[1] % or pp Deviation from initial values. Notation: 'Only Dep. Allowance Shock': $\delta^{TAX} = 25\%$, 'Combined Tax Change GN': Growth-neutral - $\delta^{TAX} = 25\%$, $\tau^{C} = 52\%$, 'Combined Tax Change GR': Growth + Fiscal Revenues - $\delta^{TAX} = 25\%$, $\tau^{C} = 32.5\%$, 'Immediate Depreciation': $\delta^{TAX} = 100\%$, 'Constant Gov Consumption': Government consumption is constant over time, gov consumption per GDP decrease.

We also make changes to relevant assumptions about government expenditures. In our baseline simulation we consider that tax measures leading to growth effects will also increase government consumption, (e. g. because of government wage effects, and indexation of transfers to income). Thus, instead of keeping government consumption constant in real terms we fix the government consumption to GDP ratio. In a robustness exercise we suspend this 'indexation' of public consumption to GDP which leads to a constant consumption level but shrinking consumption per GDP in the long run. We find that growth will be lower but the government end up with small fiscal surpluses.[11]

4 Conclusion

The question whether capital tax systems can be reformed in order to generate growth effects or reduce inequality has been widely discussed by economists and politicians. In this paper we concentrate on the relationship between the statutory profit tax rate and capital allowances. We ask if higher investment and fiscal space can be achieved at the same time with an efficient combination of profit tax rate and depreciation allowance?

In order to answer this question we use a general equilibrium framework calibrated to the German economy and tax system. Our simulations deliver some noteworthy results:

First, we find that a permanent increase of the annual tax depreciation rate by 15% increases private investment by 6.7% and GDP by almost 2.7% in the long run. But the fiscal budget becomes negative, if we assume that government consumption is indexed to GDP in the long run. However, the increase of the depreciation rate does not affect the steady state amount of capital allowances in the government budget in the long run. Thus, the long run deficit position arises solely through the higher private investment level and the constant public consumption to GDP ratio.

[11] Dorn et al. (2021) also find small positive long-run effects.

Second, we find a trade off between growth and self-financing properties of permanent changes in profit taxes and depreciation allowances: Assuming that a country is on the left-hand side of the capital tax Laffer curve, where higher tax revenues are positively associated with higher statutory capital tax rates, a government can increase long-term GDP and fiscal net revenues simultaneously by increasing capital allowance and its statutory profit tax rate in a proper proportion: If we assume a permanent increase of a statutory profit tax rate by 2.5% in combination with the higher tax depreciation rate of 15%, GDP increases similarly by 2.5%, but in contrast fiscal space also increases permanently, by 0.3 percentage points of GDP. The idea to use two instruments (statutory profit tax rate and the capital allowances) in order to reduce the trade off between to targets (growth and fiscal revenues) is an application of the Tinbergen (1952) rule to the capital tax system.

Third, the short and medium run trade off in case of depreciation allowances is less favorable compared to the long run. Therefore, if governments are constrained by debt limits (e.g. a debt brake) in the short and medium run a time-variant Tinbergen rule of the capital tax system, with higher profit tax rate increases in the medium term than in the short and long run could be more favorable. Furthermore, our result is interesting with respect to the political debate about compensating poorer households that are relatively hard hit by the COVID-19 pandemics through transfers. Although we do not analyze the political equilibrium in detail, our results seem to provide a compromise solution for political parties who negotiate about future targets: Governments with only redistribution targets could use the capital tax reform in order to maximize redistribution without hindering economic growth. Governments with a strong incentive for economic growth could increase investment and GDP without reducing transfers. Finally, each coalition or party between these stylized extreme positions can choose a combination in between.

5 Appendix

5.1 Tables

Table 3: Matching Macro and Fiscal Policy

	Notation	Value	CAN	DEU	FRA	ITA	JPN	UK	USA
Macroeconomy									
Private Consumption	$\frac{\overline{C}}{\overline{Y}}$	% of GDP	0.55	0.56	0.56	0.59	0.59	0.60	0.68
Durable Consumption	$\frac{\overline{ID}}{\overline{Y}}$	% of GDP	0.10	0.11	0.08	0.09	0.07	0.10	0.10
Private Investment	$\frac{\overline{I}}{\overline{Y}}$	% of GDP	0.18	0.18	0.17	0.18	0.19	0.18	0.17
Net Exports	$\frac{\overline{NX}}{\overline{Y}}$	% of GDP	0.03	0.05	0.00	0.01	-0.01	0.00	-0.04
Wage income per GDP	$\frac{\overline{w}\overline{N}}{\overline{Y}}$	% of GDP	0.52	0.53	0.50	0.45	0.53	0.52	0.58
Kapital Output Ratio	$\frac{\overline{k}}{\overline{Y}}$	% of GDP	2.29	2.99	2.86	3.28	2.77	2.28	2.25
Tax Rate									
Wage income tax	τ^W	%	0.25	0.33	0.44	0.47	0.23	0.25	0.25
Corporate tax	τ^C	%	0.26	0.29	0.27	0.27	0.29	0.18	0.24
VA tax	τ^{VAT}	%	0.07	0.19	0.2	0.22	0.08	0.20	0.08
Social contributions	sbr	%	0.07	0.14	0.15	0.1	0.15	0.09	0.07
Tax Depreciation Rate	δ^{TAX}	%	0.025	0.025	0.025	0.026	0.025	0.025	0.025
Revenue per GDP									
Wage income tax	$\frac{\overline{T}^W}{\overline{Y}}$	% of GDP	0.13	0.18	0.22	0.21	0.12	0.12	0.15
Effective Corporate tax	$\frac{\overline{T}^C - A}{\overline{Y}}$	% of GDP	0.06	0.06	0.07	0.09	0.06	0.04	0.05
Corporate tax rev	$\frac{\overline{T}^C}{\overline{Y}}$	% of GDP	0.11	0.11	0.11	0.14	0.12	0.08	0.09
VA tax	$\frac{\overline{T}^{VAT}}{\overline{Y}}$	% of GDP	0.05	0.10	0.11	0.13	0.05	0.12	0.07
Social contributions	$\frac{\overline{SB}}{\overline{Y}}$	% of GDP	0.04	0.07	0.08	0.04	0.06	0.05	0.05
Expenditures per GDP									
Public Consumption	$\frac{\overline{G}}{\overline{Y}}$	% of GDP	0.20	0.19	0.23	0.19	0.19	0.19	0.15
Public Investment	$\frac{\overline{IG}}{\overline{Y}}$	% of GDP	0.04	0.02	0.04	0.03	0.04	0.03	0.04
Interest Rate Payments	$\frac{\overline{IG}}{\overline{Y}}$	% of GDP	0.04	0.02	0.04	0.07	0.02	0.02	0.04
Capital allowance	$\frac{\overline{A}}{\overline{Y}}$	% of GDP	0.04	0.05	0.05	0.05	0.06	0.03	0.04
Fiscal Balance									
Transfers[1]	$\frac{\overline{T}}{\overline{Y}}$	% of GDP	0.01	0.17	0.17	0.20	0.04	0.09	0.09
Debt to GDP	$\frac{\overline{b}}{\overline{Y}}$	% of GDP	0.89	0.60	0.98	1.40	2.37	0.81	1.07

Source: AMECO, OECD National Accounts, OECD Tax Database. [1] Empirically, this component is defined as other expenditures minus other revenues, but it mainly consists of transfers and grants to households and firms. Thus, empirically it could also be understood as distributional component. In the model this variable is an indicator of fiscal surpluses/deficits and thus it measures the fiscal space which must not primarily transfered to households.

5.2 Figures

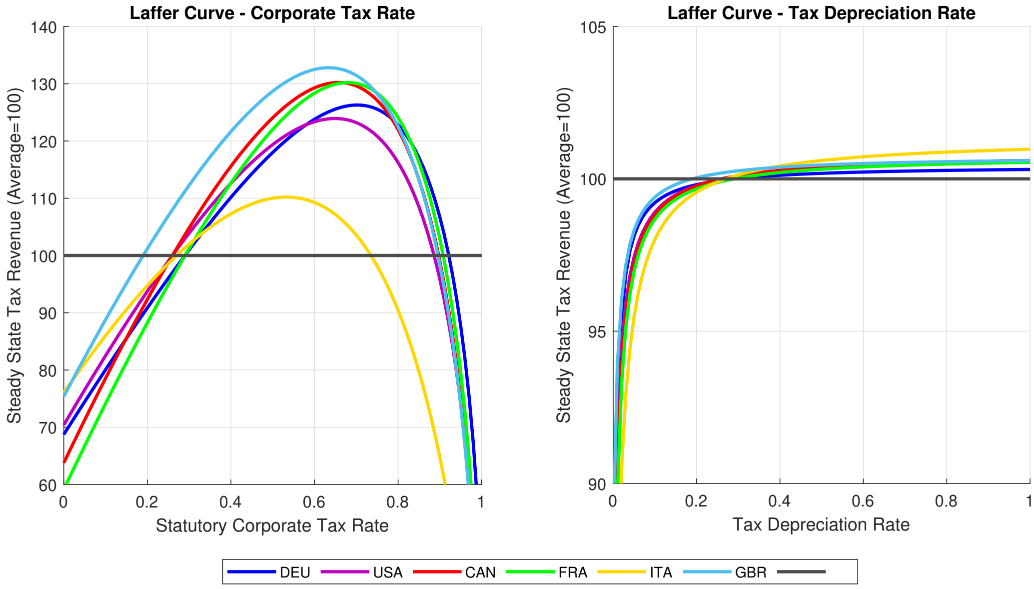

Figure 5: Laffer Curves for Capital Tax System

The Laffer Curves result from simulations of the model with country-specific parameter values.

5.3 Model Equations

(1) Production function

$$Y_t = A\, K_t^{\alpha^K}\, N_t^{\alpha^N}\, (K_t^G)^{\alpha^{KG}} \tag{15}$$

(2) Labor demand

$$w_t = \alpha^N \frac{Y_t}{N_t} \left(1 - \left(\mu^P + \gamma^P \left(\beta \left(\theta^P\, \pi_{t+1}^Y + \left(1 - \theta^P\right) \pi_{t-1}^Y\right) - \pi_t^Y\right)\right)\right) \tag{16}$$

(3) Investment demand

$$Q_t = \alpha^K \frac{Y_t}{K_t} \left(1 - \left(\mu^P + \gamma^P \left(\beta \left(\theta^P\, \pi_{t+1}^Y + \left(1 - \theta^P\right) \pi_{t-1}^Y\right) - \pi_t^Y\right)\right)\right)$$
$$\left(1 - \left(\tau^C + e_t^{\tau,C}\right)\right) + \frac{Q_{t+1}\,(1-\delta)}{1+r_t} + \left(DP_t - \frac{(1-\delta)\, DP_{t+1}}{1+r_t}\right) \tag{17}$$

(4) Investment price

$$Q_t = 1 + \gamma^K \left(\frac{I_t}{K_{t-1}} - \bar{I}^K\right) + \gamma^I\,(I_t - I_{t-1}) - \gamma^I\, \frac{\beta U'(C_{t+1}^R)}{U'(C_t^R)}\,(I_{t+1} - I_t) \tag{18}$$

(5) Capital accumulation

$$I_t = K_t - (1-\delta)\, K_{t-1} \tag{19}$$

(6) Net Present Value Capital Allowance

$$NPV_t^A = \left(\tau^C + e_t^{\tau,C}\right)\left(\delta^{TAX} + e_t^{DP}\right) + NPV_{t+1}^A\, \frac{1 - (\delta^{TAX} + e_t^{DP})}{1+r_t} \tag{20}$$

(7) Retail Price Setting (Non-durables)

$$P_t^{ret,N} = 1 + \mu^{P,ret} + \gamma^{P,ret}\left(\beta\left(\pi_{t+1}^{ret,N}\right) - \left(\pi_t^{ret,N}\right)\right) \tag{21}$$

(8) Retail Price Inflation (Non-durables)

$$\pi_t^{ret,N} - \pi_t^Y = \frac{P_t^{ret,N}}{P_{t-1}^{ret,N}} - 1 \tag{22}$$

(9) Retail Price Setting (Durables)

$$P_t^{ret,D} = 1 + \mu^{P,ret} + \gamma^{P,ret}\left(\beta\left(\pi_{t+1}^{ret,D}\right) - \left(\pi_t^{ret,D}\right)\right) \tag{23}$$

(10) Retail Price Inflation (Durables)

$$\pi_t^{ret,D} - \pi_t^Y = \frac{P_t^{ret,D}}{P_{t-1}^{ret,D}} - 1 \tag{24}$$

(11) Marginal Disutility of Labor

$$U'(N_t) = -\omega N_t^{\rho} \tag{25}$$

(12) Real Wage (in terms of CPI)

$$w_t^{CPI} = \frac{w_t}{P_t^C} \tag{26}$$

(13) Wage setting

$$\frac{-U'(N_t)}{1-\overline{\tau}^W}\left(1+\mu^W+\gamma^W\left(\beta\left(\theta^W\pi_{t+1}^W+\left(1-\theta^W\right)\pi_{t-1}^W\right)-\pi_t^W\right)\right) = w_t^C\left(s^L U'(C_t^L)+\left(1-s^L\right)U'(C_t^R)\right) \tag{27}$$

(14) Aggregate Resource Constraint

$$Y_t = I_t + s^L\left(ND_t^L + ID_t^L\right) + \left(1-s^L\right)\left(ND_t^R + ID_t^R\right) + G_t + I_t^G \tag{28}$$

(15) Non-Durables Composition

$$ND_t = s^L ND_t^L + \left(1-s^L\right) ND_t^R \tag{29}$$

(16) Durables Composition

$$ID_t = s^L ID_t^L + \left(1-s^L\right) ID_t^R \tag{30}$$

(17) Durable Stock Composition

$$D_t = s^L D_t^L + \left(1-s^L\right) D_t^R \tag{31}$$

(18) Marginal Utility of Consumption (Ricardian Households)

$$U'(C_t^R) = \frac{1}{C_t^{R^{\sigma}}} \tag{32}$$

(19) Intertemporal Consumption (Ricardian Households)

$$\frac{U'(C_t^R)}{U'(C_{t+1}^R)} = \frac{\beta\,(1+r_t)}{1+\pi_{t+1}^{C,R}} \tag{33}$$

(20) Consumer Price Index (Ricardian Households)

$$(P_t^{C,R})^{1-\sigma^{ND}} = \gamma^{N,R}\left(P_t^{ret,N}\left(1+\tau^{VAT,N}\right)\right)^{1-\sigma^{ND}} + \gamma^{D,R}\left(P_t^{ret,D}\left(1+\tau^{VAT,D}\right)\left(1+\gamma^D\left(\frac{ID_t^R}{D_t^R}-\delta^D\right)\right)\right)^{1-\sigma^{ND}}$$
$$\left(\delta^D + r_t - \left(\pi_{t+1}^{ret,D} - \pi_{t+1}^{Y}\right)\right)^{1-\sigma^{ND}} \tag{34}$$

(21) Consumer Price Inflation (Ricardian Households)

$$\pi_t^{C,R} = \frac{P_t^{C,R}}{P_{t-1}^{C,R}} - 1 \tag{35}$$

(22) Non-Durables Demand (Ricardian Households)

$$ND_t^R = C_t^R\,\gamma^{N,R}\left(\frac{P_t^{C,R}}{P_t^{ret,N}\,(1+\tau^{VAT,N})}\right)^{\sigma^{ND}} \tag{36}$$

(23) Durables Demand (Ricardian Households)

$$D_t^R = C_t^R \gamma^{D,R} \left(\frac{\frac{P_t^{C,R}}{P_t^{ret,D}\left(1+\tau^{VAT,D}\right)\left(1+\gamma^D\left(\frac{ID_t^R}{D_t^R}-\delta^D\right)\right)}}{\delta^D + r_t - \left(\pi_{t+1}^{ret,D} - \pi_{t+1}^{Y}\right) - \gamma^D \left(\frac{ID_{t+1}^R}{D_t^R} - \delta^D\right) + \gamma^D \left(\frac{ID^R{}_t}{D_{t-1}^R} - \delta^D\right)} \right)^{\sigma^{ND}} \tag{37}$$

(24) Durables Accumulation (Ricardian Households)

$$D_t^R = ID_t^R + D_{t-1}^R \left(1 - \delta^D\right) \tag{38}$$

(25) Marginal Utility of Consumption (Liquidity-Constraint Households)

$$U'(C_t^L) = \frac{1}{C_t^{L^\sigma}} \tag{39}$$

(26) Budget Constraint (Liquidity-Constraint Households)

$$ND_t^L \left(1 + \tau^{VAT,N}\right) + ID_t^L \left(1 + \tau^{VAT,D}\right) = N_t w_t \left(1 - \overline{\tau}^W\right) \tag{40}$$

(27) Consumer Price Index (Liquidity-Constraint Households)

$$(P_t^{C,L})^{1-\sigma^{ND}} = \gamma^{N,L} \left(P_t^{ret,N} \left(1 + \tau^{VAT,N}\right)\right)^{1-\sigma^{ND}} + \gamma^{D,L} \left(P_t^{ret,D} \left(1 + \tau^{VAT,D}\right) \left(1 + \gamma^D \left(\frac{ID_t^L}{D_t^L} - \delta^D\right)\right)\right)^{1-\sigma^{ND}}$$
$$\left(\delta^D + \frac{1-\beta}{\beta} - \left(\pi_{t+1}^{ret,D} - \pi_{t+1}^{Y}\right) + g_{t+1}^{C,L} + \pi_{t+1}^{C,L}\right)^{1-\sigma^{ND}} \tag{41}$$

(28) Consumer Price Inflation (Liquidity-Constraint Households)

$$\pi_t^{C,L} = \frac{P_t^{C,L}}{P_{t-1}^{C,L}} - 1 \tag{42}$$

(29) Non-Durables Demand (Liquidity-Constraint Households)

$$ND_t^L = C_t^L \gamma^{N,L} \left(\frac{P_t^{C,L}}{P_t^{ret,N}\,(1 + \tau^{VAT,N})}\right)^{\sigma^{ND}} \tag{43}$$

(30) Durables Demand (Liquidity-Constraint Households)

$$D_t^L = C_t^L \gamma^{D,L} \left(\frac{\frac{P_t^{C,L}}{P_t^{ret,D}\left(1+\tau^{VAT,D}\right)\left(1+\gamma^D\left(\frac{ID_t^L}{D_t^L}-\delta^D\right)\right)}}{\delta^D + \frac{1-\beta}{\beta} - \left(\pi_{t+1}^{ret,D} - \pi_{t+1}^{Y}\right) + g_{t+1}^{C,L} + \pi_{t+1}^{C,L} - \gamma^D \left(\frac{ID_{t+1}^L}{D_t^L} - \frac{ID_t^L}{D_{t-1}^L}\right)} \right)^{\sigma^{ND}} \tag{44}$$

(31) Consumption Growth Rate (Liquidity-Constraint Households)

$$g_t^{C,L} = \frac{C_t^L}{C_{t-1}^L} - 1 \tag{45}$$

(32) Durable Accumulation (Liquidity-Constraint Households)

$$D_t^L = ID_t^L + \left(1 - \delta^D\right) D_{t-1}^L \tag{46}$$

(33) Implicit Discount Factor (Liquidity-Constraint Households)

$$r_t^L = g_{t+1}^{C,L} + \pi_{t+1}^{C,L} \tag{47}$$

(34) Government Bonds Yield

$$1 + r_t^B = (1 + r_t) \left(1 - \frac{u_t^B}{U'(C_t^R)}\right) \tag{48}$$

(35) Government Budget Balance

$$B_t = \left(1 + r_{t-1}^B\right) B_{t-1} + A_t + I_t^G + G_t + T_t$$
$$\overline{\tau}^W w_t N_t - \left(\tau^C + e_t^{\tau,C}\right) (Y_t - N_t w_t) - ND_t \tau^{VAT,N} - ID_t \tau^{VAT,D} \tag{49}$$

(36) Debt Rule

$$b_t = \frac{\overline{B}}{4\overline{Y}} \tag{50}$$

(37) Public Consumption

$$G_t = g^Y Y_t \tag{51}$$

(38) Public Investment

$$I_t^G = g^{I,Y} \tag{52}$$

(39) Public Capital Stock

$$K_t^G = I_t^G + (1 - \delta) K_{t-1}^G \tag{53}$$

(40) Debt to GDP Ratio

$$b_t = \frac{B_t}{4Y_t} \tag{54}$$

(41) Corporate Tax Revenue

$$T_t^{C,REV} = \left(\tau^C + e_t^{\tau,C}\right) (Y_t - N_t w_t) \tag{55}$$

(42) Income Tax Revenue

$$T_t^{W,REV} = N_t w_t \overline{\tau}^W \tag{56}$$

(43) Value Added Tax Revenue

$$T_t^{VAT,REV} = ND_t \tau^{VAT,N} + ID_t \tau^{VAT,D} \tag{57}$$

(44) Government Capital Allowances

$$A_t = \left(1 - \delta^{TAX}\right) \overline{A}^{-1} + \left(\tau^C + e_t^{\tau,C}\right) \left(\delta^{TAX} + e_t^{DP}\right) + \left(1 - \left(\delta^{TAX} + e_t^{DP}\right)\right) A_{t-1}^0 \tag{58}$$

(45) Nominal Interest Rate (in PPI terms)

$$i_t = \pi^Y_{t+1} + r_t \tag{59}$$

(46) Monetary Policy Rate

$$i_t = (1-\phi^i)\left(\frac{1-\beta}{\beta} + \phi^\pi\left(\pi^C_t\right) + \phi^y \frac{Y_t}{\overline{Y}} + \phi^{dy}\left(Y_t - Y_{t-1}\right)\right) + \phi^i\, i_{t-1} \tag{60}$$

(47) Real Wage Dynamics

$$w_t = \frac{w_{t-1}\left(1+\pi^W_t\right)}{1+\pi^Y_t} \tag{61}$$

(48) Total Consumption

$$C_t = ND_t + ID_t \tag{62}$$

(49) Consumption Price Index

$$P^C_t = P^{ret,N}_t s^{ND}\left(1+\tau^{VAT,N}\right) + P^{ret,D}_t\left(1-s^{ND}\right)\left(1+\tau^{VAT,D}\right) \tag{63}$$

(50) Consumption Price Inflation

$$1+\pi^C_t = \left(1+\pi^Y_t\right)\frac{P^C_t}{P^C_{t-1}} \tag{64}$$

(51) Real interest rate

$$rr_t = i_t - \pi^C_{t+1} \tag{65}$$

5.4 Calibration

Table 4: Parameter Values

Name	**Parameter**	**Value**	**Target**
Structural parameter			
Labor prod. elasticity	α^N	0.675	$\frac{\overline{w}\overline{N}}{\overline{Y}}$
Private capital prod. elasticity	α^K	0.325	$1-\alpha^N$
Public capital prod. elasticity	α^{KG}	0.080	
Time preference	β	0.996	annualized $\approx 1.6\%$
Depreciation rate (economically)	δ	0.014	$\frac{K}{Y}$
Labour supply elasticity	ρ	0.5	
Price markup	μ^P	0.1	10% price markup
Wage markup	μ^W	0.1	10% wage markup
Ratios			
Share of LC households	s^L	0.28	Direct Match
Government consumption per GDP	g^Y	0.2	See table 3

Table 4 – Continued

Name	**Parameter**	**Value**	Target
Pub investment per GDP	ig^Y	0.025	See table 3
Adjustment costs			
Price adj. costs	γ^P	20	Burgert et al. (2020)
Wage adj. costs	γ^W	120	Burgert et al. (2020)
Retail price adj. costs	$\gamma^{P,ret}$	16	Burgert et al. (2020)
Capital adj. costs	γ^K	20	Burgert et al. (2020)
Inv. adj. costs	γ^I	15	
Durable, Non-Durables and Investments			
Depreciation rate (durables)	δ^D	0.025	
Durable consumption/consumption	s^D	0.11	See table 3
SE between durables and non-durables	σ^{ND}	0.75	
Fiscal policy			
Tax depreciation rate	Δ^{TAX}	0.026	annualized 10%
Corporate tax rate	τ^C	0.300	See table 3
Value added tax rate	$\overline{\tau}^{VAT}$	0.175	See table 3
Wage income tax rate	$\overline{\tau}^W$	0.33	See table 3
Debt level	$\overline{B}$	2.400	See table 3
Monetary policy			
Interest smoothing	ϕ^i	0.9	
Inflation target	ϕ^π	1.5	
Output gap target	ϕ^y	0.0	
Output growth target	ϕ^{dy}	0.0	

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