Climate Policies, Investments, and the Role of Elections

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Abstract

We study the interaction of climate policies and investments into fossil and renewable energy generation capacity under political uncertainty caused by democratic elections. We develop an overlapping generations model, where elected governments determine carbon taxation and green investment subsidies, and individuals invest. Some fossil investments become stranded assets if the party offering the higher carbon tax is unexpectedly elected. By using the subsidy, the government can influence investments and, therefore, the climate policy of its successor to reduce or avoid stranded assets. With endogenous reelection probability, the subsidy can also be used strategically to manipulate the reelection probabilities.

Keywords: Stranded Assets, Elections, Fossil Fuel, Renewable Energy, Carbon Tax, Investment Subsidy

JEL classification: D72, H23, Q54, Q58

Introduction

In order to avoid dangerous anthropogenic climate change, drastic mitigation policies are necessary to curb greenhouse gas emissions.[1] However, the positions of political parties differ considerably with respect to specific measures and their stringency. For example, the Trump administration withdrew from the Paris Agreement during his first term and, at the start of his second term, initiated the withdrawal process again. In contrast, the Biden administration rejoined the agreement during his presidency. Therefore, elections give rise to political uncertainty regarding future climate policies. This uncertainty creates

[1] Concerning fossil reserves, McGlade and Ekins (2015) estimate that about one third of global oil, one half of global gas and 80% of global coal reserves must be left unburned to limit global warming to 2°C.

risk for investments in long-lived clean and emission intensive assets. Investors already acknowledge the risk that some of the emission intensive assets may become stranded (Bolton and Kacperczyk, 2021).[2] In other words, political uncertainty influences investments in capital stocks. Moreover, the composition of capital stocks affects the impact of climate policy on the rents of consumers and investors. If climate policies are chosen by elected politicians that are concerned about the distribution of rents, the composition of the capital stock affects climate policies.

In this paper, we study the interaction of investments in clean and dirty assets and climate policies that are endogenously chosen by elected governments that, instead of maximizing social welfare, cater climate policies to their party's voters. For this purpose, we develop an overlapping generations with a carbon tax and a green investment subsidy as climate policy instruments. We account for the fact that investments in one period will generate rents in the next period. This implies that carbon taxation today will hurt investors that invested in dirty assets before. The corresponding redistribution of rents contributes to diverging policy preferences of voter groups. We show how political uncertainty about future carbon taxation can lead to stranded assets under rational expectations. In contrast to the carbon tax, the investment subsidy directly affects investments and, therefore, future capital stocks and climate policies. This allows the government to use the subsidy in a strategic way. First, the government can use the subsidy to bind the hands of its successor and avoid stranded assets. Second, the government can manipulate its reelection probability if the later is endogenous.

The recent economic literature on climate change increasingly focuses on political economy aspects of climate policies. Besley and Persson (2023) study the co-evolution of endogenous green preferences and technological transition towards cleaner production. They show that commitment problems due to elections can slow down or even prevent the green transition. Karp and Rezai (2014) use an overlapping generations model (OLG) with a renewable open access resource and a fixed capital stock. By imposing a tax on the use of the resource the government counters its overuse. This tax causes redistributional effects that benefit the old generation but harm the young, so that a conflict between the

[2] Semieniuk et al. (2022) calculate that plausible policies lead to stranded assets in the upstream oil and gas sector worth over \$1 trillion and Edwards et al. (2022) find that fossil power plants worth up to \$1.4 trillion might become stranded. However, we still see significant investments into the fossil energy sector (IEA, 2023).

generations alive arise. By transferring tax revenues towards the young, Pareto-improving positive tax rates are possible and will be implemented in different politico-economic settings. The role of altruism is analyzed by Goussebaïle (2024) in an OLG-model. He shows that climate policies chosen at different points in time are time-consistent if intergenerational altruism is sufficiently strong. If this is not the case, the time-inconsistency motivates the government to use its policy instruments - a carbon tax and an investment tax - to redistribute income from later periods to early periods. All of these contributions use probabilistic voting models with office seeking parties implying predictable equilibrium policies (no political uncertainty).[3] In contrast, Fuest and Meier (2023) analyze a two-period model with exogenous election probabilities of parties with divergent political goals. They show how this political uncertainty incentivizes the first period government to use green subsidies strategically to influence the emissions cap chosen by its successor and how this increases political polarization. Abstracting from elections, Kalkuhl et al. (2020) focus on another type of political uncertainty: They consider a model where policy makers cannot commit to announced carbon taxes and choose to deviate after investments have been made due to lobbying power or fiscal considerations. They obtain quite extreme results: Time-consistent policies imply either zero or prohibitively high carbon taxes, and no asset stranding. None of the above contributions find stranded assets in equilibrium with rational expectations.

Stranded assets are one focus in the emerging literature on political transition risk. Economists have only started to investigate the political implications of asset stranding (von Dulong et al., 2023) and most existing papers take climate policy uncertainty as exogenous (van der Ploeg and Rezai, 2020b; Diluiso et al., 2021; Bretschger and Soretz, 2022). Hambel and Van Der Ploeg (2025) assume probabilistic changes of climate policy stringency and show that this policy risk increases expected returns on fossil assets, which in turn accelerates the low-carbon transition. Barnett (2024) links the probability of a climate policy shock to climate change and finds that this may result in a "run on fossil fuels" related to the green paradox (Sinn, 2008). Empirical research shows that investors on financial markets take political transition risks into account (Bolton and Kacperczyk, 2023; Sen and von Schickfus, 2020; Fliegel, 2025).

[3] Using an OLG model with a median voter approach, Habla and Roeder (2017) show that redistributional effects leads to political distortions and climate policies, in their case mitigation and adaptation, are not set optimally.

We analyze an overlapping generations model with endogenous climate policy choices that can lead to stranded assets in equilibrium. In our model, policy uncertainty arises due to the election of parties that choose policy levels (carbon tax and green investment subsidy) to maximize the welfare of their voter groups. Investments are influenced by this policy uncertainty and can be used to either build up fossil fuel based (black) energy generation capacity or renewables based (green) capacity. The carbon tax, in turn, depends on the composition of investments. Both the carbon tax and the green investment subsidy have a distributional effect: while carbon taxation redistributes rents from owners of black capacities, the investment subsidy redistributes public funds towards investors. These effects are considered in the choice of the respective policy levels. We analyze three different cases regarding policy uncertainty: i. perfect foresight, ii. exogenously given election probabilities and iii. endogenously determined election probabilities with probabilistic voting. If individuals have perfect foresight (i.), our results are in line with Kalkuhl et al. (2020), i.e. the carbon tax is either zero or prohibitive, with black investments being zero in the latter case. In case of uncertain election outcomes (ii. and iii.), both green and black investments depend on the expected carbon tax rate and the current green investment subsidy. If individuals expect one party to win with a high probability and their expectations are met, there are no stranded assets. In contrast, if individuals expect the party offering the lower tax rate to win, their expectations aren't met and the green investment subsidy is low, some black investments become stranded assets.

The green investment subsidy may be used by the government to bind the hands of its successor. If the party representing the young generation holds office and its reelection probability is small, it can use a high subsidy rate to ensure that the succeeding government will not implement a high carbon tax in the next period, so that no black capacity gets stranded. With endogenous election probability, the party will also use the subsidy to manipulate the election probability in its favor. Our result suggests that a Y-government will increase the subsidy rate to boost its reelection probability. Consequently, both generations have more to lose in the elections and political polarization between generations increases. In contrast, the party representing the old generation abstains from climate policies to avoid a redistribution of income in favor of the young generation.

We structure the remainder of the paper as follows. In Section I, we introduce the model. We solve for the energy market equilibrium and the preferred tax rates of the parties in Sections II and III. Investment decisions are analyzed in Section IV, and Section V turns to the government's decision with respect to the subsidy rate. Section VI concludes.

I. Model

I.A. Basic assumptions

We consider an overlapping generations model in discrete time, so that at every point in time t two generations, an old one and a young one, are alive. Both generations consist of atomistic individuals and the generations' size is normalized to unity. While the lifespan of the old generation ends in period t, young individuals live until the end of the following period $t+1$. The utility function of individual j of generation $i = y, o$ is given by

$$V(b_t^{ij}, g_t^{ij}, c_t^{ij}, E_t) = U(b_t^{ij} + g_t^{ij}) + c_t^{ij} - H(E_t) \tag{1}$$

$$= \beta \left[b_t^{ij} + g_t^{ij}\right] - \frac{\gamma}{2} \left[b_t^{ij} + g_t^{ij}\right]^2 + c_t^{ij} - hE_t, \tag{2}$$

where b_t^{ij} denotes black energy (fossil fuel) consumption, g_t^{ij} green energy (renewable) consumption and c_t^{ij} consumption of a numéraire good. Climate damages caused by the CO_2 stock E_t are covered by the linear damage function $H(E_t) = hE_t$.[4] The parameters β, γ and h are positive.

Specialized capital goods (wind turbines, solar panels, coal power plants, etc.), i.e. energy generation capacities, are required to produce energy.[5] By appropriate unit choice, we assume that every capacity unit allows the production of one unit of energy, so that Z_t denotes both the black capacity at time t and the maximal amount of black energy generated at time t, i.e. aggregated black energy supply b_t^s cannot exceed capacity Z_t. Analogously, Q_t denotes the green capacity and the maximal amount of green energy available at time t, so that aggregated green energy supply g_t^s cannot be greater than capacity Q_t. We assume

$$Z_{t+1} = z_t, \tag{3}$$

[4] Linear damage functions are widely used in the literature - cf. Hoel (2011), Battaglini and Harstad (2016), Kollenbach and Schopf (2022), and Eichner and Kollenbach (2022). According to Golosov et al. (2014), the relation between the stock of CO_2 and temperature is concave, while the relation of temperature and climate damages is convex. Thus, a linear damage functions can be considered a good approximation.

[5] The accumulation of a green energy generation capacity is discussed by Tsur and Zemel (2011) and Kollenbach (2017b). Among others, Campbell (1980), Cairns (2001), and Kollenbach (2017a) analyze fossil fuel related capital investments.

$$Q_{t+1} = q_t. \tag{4}$$

Thus, similar to Battaglini and Harstad (2016), there is an investment lag implying that capacity investments z_t and q_t in period t build up new capacity in the next period $t+1$. Furthermore, the capacity of period t depreciates completely, so that the capacity of period $t+1$ only depends on investments in period t. In case of green energy, we assume that no other production factors are necessary, because the main inputs such as solar radiation or wind are freely available. In contrast, black energy production requires fossil fuels such as coal or gas. We consider the fuel reserves to be practically unlimited but costly to extract.[6]

Burning fossil fuels unleashes CO_2, which accumulates in the atmosphere according to

$$E_t = b_t^s + \delta E_{t-1} = \sum_{n=0}^{t} \delta^{t-n} b_n^s + \delta^t E_0, \tag{5}$$

where $1 - \delta \in [0,1]$ is the natural regeneration rate and $E_0 \geq 0$ the emission stock endowment.[7] We assume $\beta > 2[1 + \rho\delta]h$, where $\rho \in [0,1]$ is the discount factor.

Young individuals are exogenously endowed with income L.[8] Income is used to finance consumption of energy and the final good, and to invest into energy generation capacity.[9] The corresponding investment costs are given by z_t in case of black capacity investments and by αq_t, with $\alpha > 1$, in case of green capacity investments. Thus, the budget constraint of a young individual reads

$$L + \frac{T}{2} = c_t^{yj} + z_t^j + [\alpha - \sigma_t] q_t^j + p_b b_t^{yj} + p_g g_t^{yj}, \tag{6}$$

where p_b and p_g are the prices of black and green energy, respectively, $\sigma_t \in [0, \alpha - 1)$ is a subsidy for green capacity investments, and T is a governmental transfer. Due to (3) and (4), every young individual will own a part of Z_{t+1}^j and Q_{t+1}^j, respectively, i.e. of the energy generation capacities installed in the following period $t+1$, while the current capacities Z_t and Q_t are completely owned by the old generation. Selling the corresponding energy

[6]According to Andruleit et al. (2012), the static range of coal reserves and resources exceeds 5000 years.

[7]See Battaglini and Harstad (2016) for a similar approach.

[8]This corresponds to a model closure with the numéraire good being produced only by means of labor that is inelastically supplied by the young generation receiving labor income L.

[9]The case where only a fraction of the young generation invests into energy generation capacities is left for future research.

is the only source of income for the old generation in t. The budget constraint of an old individual j reads

$$p_b b_t^{sj} - M(b_t^{sj}) - \theta_t b_t^{sj} + p_g g_t^{sj} + \frac{T}{2} = c_t^{oj} + p_b b_t^{oj} + p_g g_t^{oj}, \tag{7}$$

where θ_t is a carbon tax , g_t^{sj} green energy supply, b_t^{sj} black energy supply and

$$M(b_t^{sj}) = \frac{m}{2}\left[b_t^{sj}\right]^2 \tag{8}$$

the corresponding extraction cost function of fossil fuels. We assume that one unit of fuel is needed to produce one unit of black energy.[10] By assuming that the government's budget is balanced in every period, we get

$$T = \theta_t b_t^s - \sigma_t q_t. \tag{9}$$

Thus, the transfer T is positive if carbon tax revenues exceed the expenditure for subsidies. The energy markets are cleared by $b_t^s = \sum_j b_t^{sj} = \sum_i \sum_j b_t^{ij}$ and $g_t^s = \sum_j g_t^{sj} = \sum_i \sum_j g_t^{ij}$.

I.B. Political system

Following Alesina and Tabellini (1990), we consider two parties Y and O, which may hold office during period t and determine the carbin tax rate θ_t and the green investment subsidy σ_t. Because all individuals of a generation are alike with the exception of ideological preferences, we assume that party Y [O] represents the young [old] generation. That is, party $i = Y, O$ sets the policy instruments such that they maximizes welfare W_t^i of the young/old generation at time t, which yields the preferred tax rates θ_t^Y and θ_t^O, and preferred subsidy rates σ_t^Y and σ_t^O. Which party holds office is determined by majority voting. We compare the benchmark case with certainty about electoral outcomes with the case with exogenously given election probabilities as well as with endogenously determined election probabilities. To solve the latter case, we assume that each individual has preferences in favor of party Y, which are given by $\Psi^{ij} + \chi$, with Ψ^{ij} denoting an ideological bias of generation i's individual j and χ indicating the general popularity of party Y. Both Ψ^{ij} and χ are uniformly distributed around mean 0 with density ξ^i and ν, respectively.[11] Thus, individual j of generation i votes for party Y if

$$W_t^{iY} + \Psi^{ij} + \chi \geq W_t^{iO} \tag{10}$$

[10] Alternatively, θ_t denotes the price of an emission certificate if an ETS is implemented.
An extraction cost function, which convexly increases in fuel extraction is also used by Tsur and Zemel (2005).

[11] Cf. Persson and Tabellini (2002, chap. 13) for a similar approach.

holds. For a given realization of the popularity χ, the indifferent voter in generation i is characterized by her ideological preferences $\tilde{\Psi}^i = W_t^{iO} - W_t^{iY} - \chi$. All individuals with a higher Ψ^{ij} vote for party Y, whereas all individuals with a lower Ψ^{ij} vote for party O. We assume that politicians are partisan and implement their parties' preferred carbon tax and investment subsidy after the elections. The vote share of party O is given by $vs^O = \frac{1}{2}\xi^o \left[\tilde{\Psi}^o + \frac{1}{2\xi^o}\right] + \frac{1}{2}\xi^y \left[\tilde{\Psi}^y + \frac{1}{2\xi^y}\right]$. In the following, we assume that $\xi^o = \xi^y = \xi$, i.e. that ideological preferences have the same distribution in both generations. Then, party O's probability of winning the elections at time t is given by

$$\pi_t = \frac{\nu}{2}\left\{ \left[W_t^{oO} - W_t^{oY}\right] + \left[W_t^{yO} - W_t^{yY}\right] \right\} + \frac{1}{2}. \tag{11}$$

The probability that the young party wins the elections is $1 - \pi_t$. We see that the party representing the generation that has more to lose if the other party is elected and implements its preferred policy has a higher probability to win the elections.

I.C. Timing

The timing in our model is is illustrated in Fig. 1. At the beginning of each period,

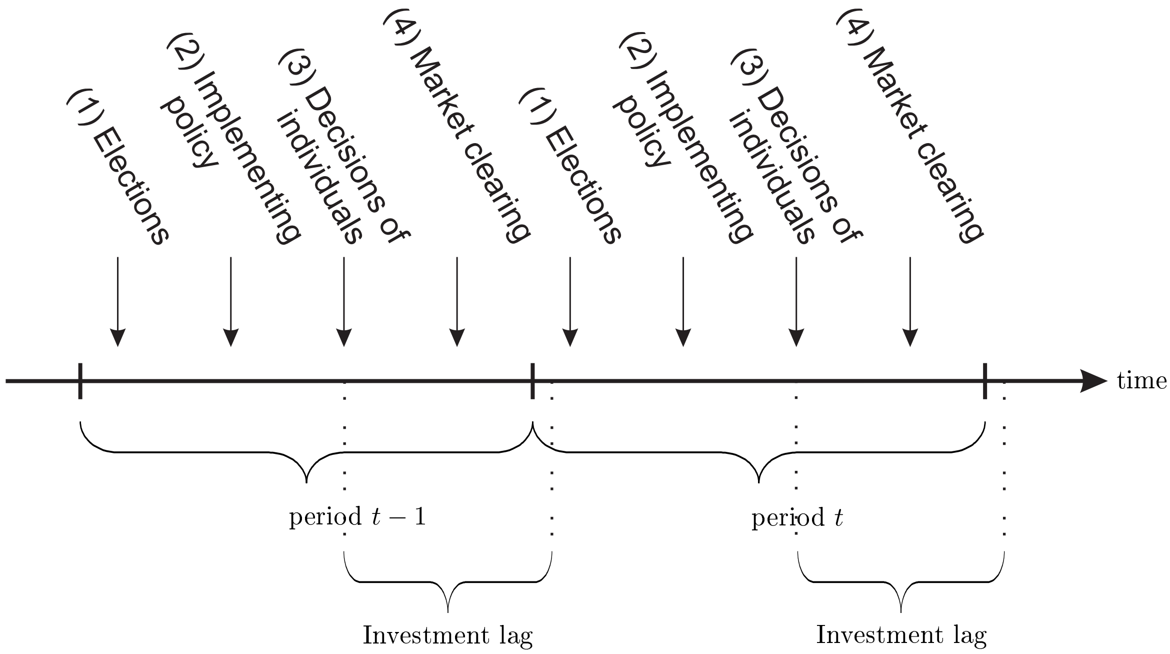

Figure 1: Timing

elections are held and the winning party sets the carbon tax and the green investment subsidy. Subsequently, individuals non-cooperatively determine their consumption levels $c_t^{ij}, b_t^{ij}, g_t^{ij}$, young individuals decide how much to invest into generation capacities and old individuals set the energy supply levels b_t^{sj}, g_t^{sj}. Finally, the markets are cleared, where we assume that all individuals are price takers. Due to the investment lag, investments made in $t-1$ are not relevant for the energy market equilibrium of that period but for the equilibrium of the following period t. This implies that the investment decision of period $t-1$ depends on the subsidy rate σ_{t-1} and on the expectations about the election outcome in period t, which determine the expected tax rate $\mathrm{E}(\theta_t) = \Theta_t$.

We determine the market equilibrium of period t by solving the four stages

1) Determine subsidy σ_{t-1},
2) Determine investments at time $t-1$,
3) Determine carbon tax θ_t given the election outcome at time t,
4) Determine energy demand, supply and market equilibrium at time t

by backward induction in the following sections.

II. Energy market

First, we present the individuals' decisions with respect to energy consumption, energy supply and capacity investments given the carbon tax rate θ_t, the investment subsidy σ_t, and the energy generation capacities Z_t and Q_t. Subsequently, we describe the energy market equilibrium at time t, which is then used to determine the preferred tax rate of party Y and of party O, the capacity investments of period $t-1$, and the preferred subsidy rate of party Y and of party O at time $t-1$. Because individuals of one generation only differ in their ideological preferences, which do not affect the aforementioned decisions, we consider one representative individual per generation.

II.A. The individuals' decision rules

By substituting (7) into (2), the indirect utility function of the representative old individual net of ideological preferences reads

$$\tilde{V}(b_t^o + g_t^o, b_t^s, g_t^s) = \beta\,[b_t^o + g_t^o] - \frac{\gamma}{2}\,[b_t^o + g_t^o]^2 + p_b b_t^s - \frac{m}{2}(b_t^s)^2 - \theta_t b_t^s + p_g g_t^s + \frac{T}{2} - p_b b_t^o - p_g g_t^o - hE_t. \tag{12}$$

The individual maximizes (12) with respect to b_t^0, g_t^o, b_t^s and g_t^s given the capacity constraints $Z_t \geq b_t^s$ and $Q_t \geq g_t^s$. Due to the atomistic population structure, the individual neglects her impact on the emission stock E_t. Assuming an interior solution with respect to energy consumption b_t^o and g_t^o, the corresponding first-order conditions yield

$$U'(b_t^o + g_t^o) = \beta - \gamma[b_t^o + g_t^o] = p_b = p_g = p_t, \tag{13}$$

(14) $$p_t = mb_t^s + \theta_t + \lambda_b,$$

(15) $$p_t = \lambda_g.$$

The complementary slackness conditions read

(16) $$(a): \lambda_b \geq 0,\ \lambda_b[Z_t - b_t^s] = 0, \qquad (b): \lambda_g \geq 0,\ \lambda_g[Q_t - g_t^s] = 0.$$

According to (13), the old individual increases her consumption of both kinds of energy until her marginal utility from energy consumption equals the energy price p_t. Because black and green energy are perfect substitutes, p_t denotes the price for both energy types. Green energy generation is not associated with any other costs than capacity investments. Consequently, (15) and (16)(b) imply that the complete stock Q_t is used.[12] In contrast, some black capacity may remain unused in period t, i.e. some black capacity may become a stranded asset. In this case, $\lambda_b = 0$ and (14) implies that black energy supply is increased until the energy price equals the sum of marginal extraction costs and the carbon tax.

For the representative young individual we get

(17) $$\begin{aligned}\tilde{V}(b_t^y + g_t^y, z_t, q_t) = \beta\,[b_t^y + g_t^y] - \frac{\gamma}{2}\,[b_t^y + g_t^y]^2 + L + \frac{T}{2} - z_t - [\alpha - \sigma_t]q_t \\ - p_t[b_t^y + g_t^y] - hE_t + \rho\tilde{V}(b_{t+1}^o + g_{t+1}^o, b_{t+1}^s, g_{t+1}^s).\end{aligned}$$

(17) is maximized with respect to b_t^y, g_t^y, z_t and q_t given the expected carbon tax rate $\mathrm{E}(\theta_{t+1}) = \Theta_{t+1}$, the expected energy price $\mathrm{E}(p_{t+1}) = P_{t+1}$ and the expected black energy supply $\mathrm{E}(b_{t+1}^s) = B_{t+1}$ of period $t+1$. Assuming an interior solution with respect to energy consumption b_t^y and g_t^y, the first-order conditions yield

(18) $$U'(b_t^y + g_t^y) = \beta - \gamma[b_t^y + g_t^y] = p_t,$$

(19) $$\rho\,[P_{t+1} - mB_{t+1} - \Theta_{t+1}] = 1, \qquad \text{if } Z_{t+1} - B_{t+1} = 0,$$

(20) $$\rho P_{t+1} = \alpha - \sigma_t.$$

Analogous to (13), (18) implies that energy consumption of the young individual equates marginal utility with the energy price. (20) shows that the discounted value of the expected marginal gain from green capacity investments (left-hand side) has to equal the respective marginal costs (right-hand side). In case of black capacity investments, the

[12] We neglect the case of a low energy demand that is not sufficient to fully use the green energy capacity, because this case is of little interest in the context of climate change.

analogous statement is only true if the individual expects that the complete capacity is used in the following period. If this is not the case, an additional black capacity investment unit causes costs but is not expected to generate any returns in the next period and is, therefore, not optimal. In other words, the young individual does not invest into what she expects to become a stranded asset.

By using (19) and (20) we get

$$Z_{t+1} = \frac{\alpha - \sigma_t - 1}{\rho m} - \frac{\Theta_{t+1}}{m}, \tag{21}$$

which constitutes a negative correlation of black capacity investments $z_t = Z_{t+1}$ with both the green investment subsidy and the expected carbon tax rate. If marginal investment costs of black and green capacity are identical ($\alpha - \sigma_t = 1$), green capacity investments are superior, because green energy supply is not taxed and not associated with extraction costs as in case of fossil fuels. In contrast, if $\alpha - \sigma_t > 1$, black capacity investments are positive as long as the expected tax rate falls short of $\frac{\alpha - \sigma_t - 1}{\rho}$.

II.B. Energy market equilibrium

Aggregate energy demand is given by

$$D(p_t) = 2\frac{\beta - p_t}{\gamma}, \tag{22}$$

while green energy supply is Q_t and the black energy supply function reads

$$b_t^s(p_t) = \min\left\{Z_t, \frac{p_t - \theta_t}{m}\right\}. \tag{23}$$

An equilibrium on the energy market requires $D(p_t) = Q_t + b_t^s(p_t)$ to hold, which yields

$$p_t = \begin{cases} \frac{2m\beta + \gamma\theta_t}{2m+\gamma} - \frac{\gamma m Q_t}{2m+\gamma}, & \text{if } b_t^s \leq Z_t, \\ \beta - \frac{\gamma}{2}\left[Q_t + Z_t\right], & \text{if } b_t^s = Z_t, \end{cases} \tag{24}$$

$$b_t^s = \begin{cases} \frac{2\beta - 2\theta_t - \gamma Q_t}{2m+\gamma}, & \text{if } b_t^s \leq Z_t, \\ Z_t, & \text{otherwise.} \end{cases} \tag{25}$$

The energy market equilibrium is illustrated in Fig. 2. In the left panel, we assume that the black capacity is not completely used, i.e. that some black investments made in $t-1$ are stranded assets. Then, $\lambda_b = 0$ and the intersection of the λ_g line with the demand curve determines total energy consumption $b_t + Q_t$ and the energy price in equilibrium. Because green energy is only used if it is cheaper than black energy, the intersection of

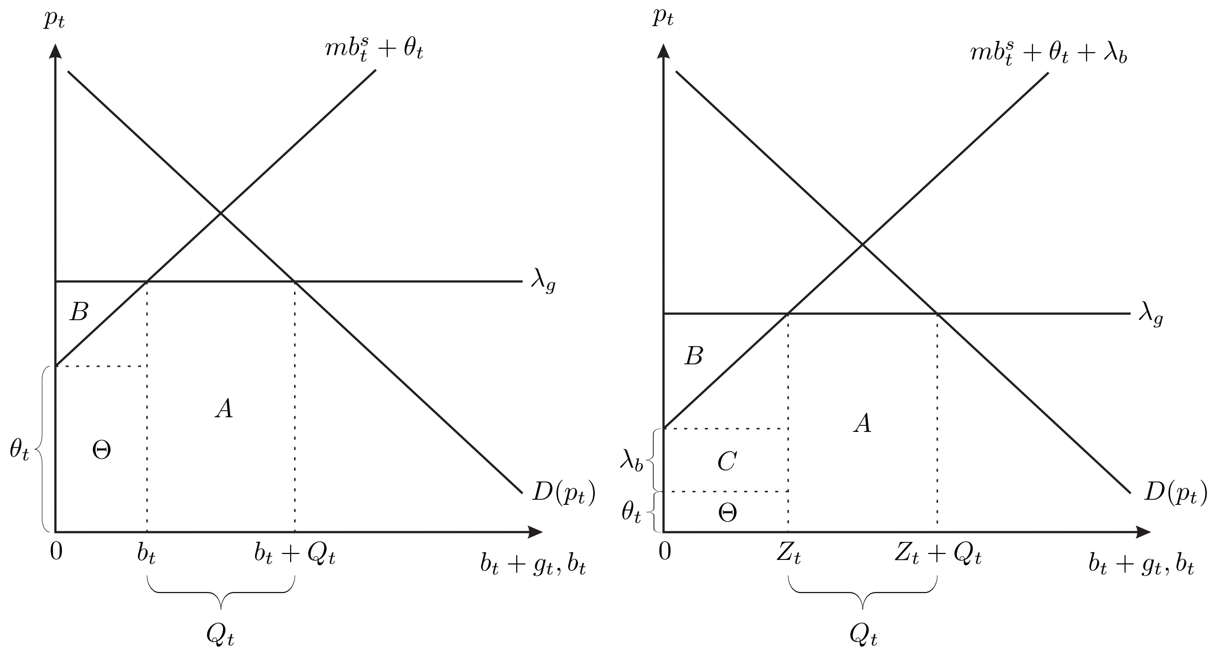

Figure 2: Equilibrium on the energy market with $b_t^s < Z_t$ (left panel) and $b_t^s = Z_t$ (right panel)

the λ_g line and the marginal black energy costs curve gives black energy consumption b_t. The difference between total energy consumption and black energy supply needs to equal green capacity Q_t, which determines the level of λ_g. Because green energy production is not associated with variable costs, area A denotes the green capacity rent. Profits from black energy supply are given by B and tax revenues by Θ. While tax revenues are equally distributed among the old and young generation, both the profits from black energy supply and the green capacity rent belong to the old generation. Differentiating the first lines of (24) and (25) with respect to the capacities Q_t and Z_t, and the tax rate θ_t yields

$$(26) \quad (a) \ \frac{\partial p_t}{\partial Q_t} = -\frac{\gamma m}{2m+\gamma} < 0, \qquad (b) \ \frac{\partial p_t}{\partial Z_t} = 0, \qquad (c) \ \frac{\partial p_t}{\partial \theta_t} = \frac{\gamma}{2m+\gamma} > 0,$$

$$(27) \quad (a) \ \frac{\partial b_t^s}{\partial Q_t} = -\frac{\gamma}{2m+\gamma} < 0, \qquad (b) \ \frac{\partial b_t^s}{\partial Z_t} = 0, \qquad (c) \ \frac{\partial b_t^s}{\partial \theta_t} = -\frac{2}{2m+\gamma} < 0.$$

Thus, a higher green capacity Q_t reduces the energy price, because the marginal green capacity rent λ_g needs to be lower to ensure the complete utilization of Q_t. Due to the lower energy price, black energy supply is also reduced implying that a higher green capacity Q_t not only leads to more energy consumption but also to a substitution of black energy by green energy. The effect of a higher capacity on the green capacity rent is ambiguous, because a higher Q_t increases the rent, while a lower price reduces it. An increase of the black capacity does not affect the equilibrium, because the capacity is not completely used.

In case of a higher tax rate θ_t, the marginal black energy cost curve is shifted upwards, so that λ_g increases to ensure that there is no excess demand for green energy. Consequently, both energy price and green capacity rent increase with the tax rate. With respect to black energy supply, two opposing effects emerge. On the one hand, a higher energy price boosts black energy supply. On the other hand, a higher tax reduces black energy supply. According to (27), the latter effect dominates.

Suppose now that the black capacity constraint binds (right panel of Fig. 2). Then, the ordinate-intercept of the marginal black energy cost curve equals the sum of $\lambda_b \geq 0$ and θ_t. Again, the intersection of the λ_g line with the demand curve determines total energy consumption and the energy price. However, λ_b is now such that the intersection of the λ_g line with the marginal black energy costs curve implies a black energy supply of $b_t^s = Z_t$, while λ_g ensures that the difference between total energy consumption and Z_t equals Q_t. As in case of a non-binding capacity constraint, areas A and Θ denote the green capacity rent and the tax revenues, respectively. The profits of black energy supply are now given by the sum of B and C, where C is the black capacity rent.

Differentiating the second lines of (24) and (25) with respect to the capacities Q_t and Z_t, and the tax rate θ_t yields

$$(28) \qquad (a)\ \frac{\partial p_t}{\partial Q_t} = -\frac{\gamma}{2} < 0, \qquad (b)\ \frac{\partial p_t}{\partial Z_t} = -\frac{\gamma}{2} < 0, \qquad (c)\ \frac{\partial p_t}{\partial \theta_t} = 0,$$

$$(29) \qquad (a)\ \frac{\partial b_t^s}{\partial Q_t} = 0, \qquad (b)\ \frac{\partial b_t^s}{\partial Z_t} = 1 > 0, \qquad (c)\ \frac{\partial b_t^s}{\partial \theta_t} = 0.$$

Because both capacities are completely used, an increase of Q_t and Z_t lowers the energy price. However, a higher green capacity does not affect black energy supply, due to the binding black capacity constraint. In contrast, the binding constraint implies that every additional black capacity unit is used and, therefore, increases fuel supply. The binding black capacity constraint also explains why the tax rate neither affects the energy price nor black energy supply. Rather, differentiating $p_t = mZ_t + \theta_t + \lambda_b$ shows that a higher tax rate only reduces the black capacity rent. That is, the higher the tax rate, the smaller [larger] area C [Θ] in Fig. 2 (right panel).

By taking (3) and (4) into account, the expected energy price of period $t+1$ can be written as $P_{t+1} = P_{t+1}(q_t, z_t, \Theta_{t+1})$, with $\frac{\partial P_{t+1}}{\partial q_t} < 0$, $\frac{\partial P_{t+1}}{\partial z_t} \leq 0$, and $\frac{\partial P_{t+1}}{\partial \Theta_{t+1}} \geq 0$. Substituting into (20) and (21) yields $z_t = z_t(\sigma_t, \Theta_{t+1})$ and $q_t = q_t(\sigma_t, \Theta_{t+1})$, with

$$(30) \qquad (a)\ \frac{\partial z_t}{\partial \sigma_t} = -\frac{1}{\rho m} < 0, \qquad (b)\ \frac{\partial z_t}{\partial \Theta_{t+1}} = -\frac{1}{m} < 0,$$

$$(31) \qquad (a)\ \frac{\partial q_t}{\partial \sigma_t} = \frac{\frac{1}{\rho m}\frac{\partial P_{t+1}}{\partial z_t} - \frac{1}{\rho}}{\frac{\partial P_{t+1}}{\partial q_t}} > 0, \qquad (b)\ \frac{\partial q_t}{\partial \Theta_{t+1}} = \frac{\frac{1}{m}\frac{\partial P_{t+1}}{\partial z_t} - \frac{\partial P_{t+1}}{\partial \Theta_{t+1}}}{\frac{\partial P_{t+1}}{\partial q_t}} \geq 0.$$

Ceteris paribus, both a higher subsidy and a higher expected tax rate boost green capacity investments but depress black capacity investments.

III. Preferred tax rates

If party $i = O, Y$ holds office in period t, it sets the carbon tax θ_t^i such that it maximizes welfare

$$(32) \qquad \begin{aligned} W_t^o = {} & \beta\left[b_t^o(\theta_t) + g_t^o(\theta_t)\right] - \frac{\gamma}{2}\left[b_t^o(\theta_t) + g_t^o(\theta_t)\right]^2 - p_t(\theta_t)\left[b_t^o(\theta_t) + g_t^o(\theta_t)\right] \\ & + p_t(\theta_t) b_t^s(\theta_t) - \frac{m}{2}\left[b_t^s(\theta_t)\right]^2 - \theta_t b_t^s(\theta_t) + p_t(\theta_t) Q_t \\ & + \frac{\theta_t b_t^s(\theta_t) - \sigma_t q_t(\sigma_t, \Theta_{t+1})}{2} - h\left[b_t^s(\theta_t) + \delta E_{t-1}\right], \end{aligned}$$

$$(33) \qquad \begin{aligned} W_t^y = {} & \beta\left[b_t^y(\theta_t) + g_t^y(\theta_t)\right] - \frac{\gamma}{2}\left[b_t^y(\theta_t) + g_t^y(\theta_t)\right]^2 - p_t(\theta_t)\left[b_t^y(\theta_t) - g_t^y(\theta_t)\right] + L \\ & - [\alpha - \sigma_t] q_t(\sigma_t, \Theta_{t+1}) - z_t(\sigma_t, \Theta_{t+1}) + \frac{\theta_t b_t^s(\theta_t) - \sigma_t q_t(\sigma_t, \Theta_{t+1})}{2} \\ & - h\left[b_t^s(\theta_t) + \delta E_{t-1}\right] + \rho\left\{\pi_{t+1} W_{t+1}^{oO} + [1 - \pi_{t+1}] W_{t+1}^{oY}\right\} \end{aligned}$$

of the generation the party represents. Restricting our analysis to non-negative tax rates, the first-order conditions give[13]

$$(34) \qquad \theta_t^O = \begin{cases} \theta_t^{Ob} = \frac{4m+\gamma}{2} Q_t + \frac{4m+2\gamma}{\gamma} h - \frac{2m}{\gamma}\beta, & \text{if } b_t^s \leq Z_t, \\ \theta_t^{OZ} = 0, & \text{if } b_t^s = Z_t, \end{cases}$$

$$(35) \qquad \theta_t^Y = \begin{cases} \theta_t^{Yb} = -\frac{\gamma}{2} Q_t + \frac{4m+2\gamma}{4m+\gamma}[1 + \rho\delta] h + \frac{2m}{4m+\gamma}\beta, & \text{if } b_t^s \leq Z_t, \\ \theta_t^{YZ} = -\frac{\gamma}{2} Q_t - \frac{2m+\gamma}{2} Z_t + \beta, & \text{if } b_t^s = Z_t. \end{cases}$$

From (34) and (35) we directly infer

Proposition 1

a) Suppose the black capacity constraint binds. Then, the preferred carbon tax rate of the young party decreases with both types of capacities $\left(\frac{\partial \theta_t^{YZ}}{\partial Q_t}, \frac{\partial \theta_t^{YZ}}{\partial Z_t} < 0\right)$*, while the preferred carbon tax rate of the old party is nil.*

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[13] See Appendix A.A. Note that the linearity of the damage function implies that the probability π_{t+1} and the expected tax rate Θ_{t+1} do not depend on the current tax rate θ_t. The analysis of the preferred subsidy rates is postponed to section V, because it requires the expected tax rate .

b) Suppose the black capacity constraint does not bind. Then, the preferred carbon tax rate of the young party decreases with the green capacity $\left(\frac{\partial \theta_t^{Yb}}{\partial Q_t} < 0\right)$ *whereas the preferred carbon tax rate of the old party increases with the green capacity* $\left(\frac{\partial \theta_t^{Ob}}{\partial Q_t}\right) > 0$*. The black capacity has no impact on the preferred tax rates.*

Consider a binding black capacity constraint. Then, environmental damages are fixed, so that the preferred carbon tax rates do not depend on h. Rather, the tax only redistributes the black capacity rent. While the rent belongs to the old generation only, 50% of tax revenues are distributed to the young generation. Consequently, party O prefers a tax rate of zero, so that there is no redistribution. In contrast, the preferred tax $p_t - mZ_t$ of party Y eliminates λ_b implying that 50% of the black capacity rent is redistributed to the young generation.

In case of a non-binding black capacity constraint, the effect of a higher green capacity differs between the tax rates. A higher green capacity increases the preferred tax rate of party O but decreases the preferred tax rate of party Y. Both effects are driven by the green capacity rent. (26)(a) shows that the energy price and, therefore, the marginal rent decreases with a higher capacity. To counter this effect, party O takes (26)(c) into account, i.e. that a higher tax boosts the energy price. Because the young generation only has to pay for the green capacity rent, party Y prefers the tax rate to decrease with Q_t, so that the depressing effect of a higher capacity Q_t on the marginal rent is amplified. Both party O and party Y prefer a higher tax rate if the environmental problem is more serious, i.e. if the marginal climate damage h is higher. In case of party Y, the term $[1 + \rho\delta]$ reflects that the young generation of period t suffers from higher emissions in the current and in the following period.

Finally, let us verify whether the preferred tax rates can be used to implement the social optimum. The taxation of black energy is only necessary, if the black capacity does not equal its socially optimal value. Consequently, θ_t^{OZ} is only optimal in the knife-edge case that the black capacity Z_t is socially optimal. In contrast, θ_t^{YZ} is never socially optimal, because the social planner has no interests in income redistribution as long as the individuals' marginal utilities are identical, which is ensured by (13) and (18). In case of an inefficiently high black capacity, neither θ_t^{Ob} nor θ_t^{Yb} can implement the socially optimal fuel use, because both tax rates take only the climate damages into account that occur during the lifespan of the old or young generation, respectively. In contrast, the social planner considers all following generations and, therefore, the climate damages for all points in time $\tilde{t} \geq t$.[14] Proposition 2 follows directly.

Proposition 2 *Neither of the preferred carbon tax rates of party O and Y is socially optimal.*

IV. Optimal investments

The capacities Q_t and Z_t are equal to the investments made in the preceding period $t-1$. Because the optimization problem is the same for every young generation, (19) and (20) hold for every period. Thus, the capacity investments made in $t-1$ depend on the investment subsidy rate σ_{t-1} and the expectations of the young generation in $t-1$ about the energy price, fuel supply and the carbon tax rate in period t. The representative young individual of period $t-1$ expects that party O [Y] wins and implements its preferred tax rate θ_t^o [θ_t^y] with probability π [$1-\pi$].

IV.A. Perfect foresight

At first, suppose that the young generation of period $t-1$ has perfect foresight, so that $\Theta_t = \theta_t$, where θ_t is given by either (34) or (35). In Appendix A.B we prove

Proposition 3 *Suppose that the young generation of period $t-1$ has perfect foresight.*

- *If party O wins the elections in period t, the carbon tax rate θ_t is zero, and capacities are given by*

$$Z_t = \frac{\alpha - \sigma_{t-1} - 1}{m\rho}, \quad Q_t = \frac{2}{\gamma}\beta + \frac{1}{\rho m} - \frac{2m+\gamma}{\gamma}\frac{\alpha - \sigma_{t-1}}{\rho m}.$$

- *If party Y wins the elections in period t, the carbon tax rate θ_t equals $p_t - mZ_t$, and capacities are given by*

$$Z_t = 0, \quad Q_t = \frac{2}{\gamma}\left[\beta - \frac{\alpha - \sigma_{t-1}}{\rho}\right].$$

With perfect foresight, the black capacity constraint binds, because the investment costs are positive. In period $t-1$, the representative young individual equates the expected marginal profits to the marginal investment costs. However, investment costs are sunk in period t, so that the individual would like to supply more black energy in t than possible due to the limited capacity.

If party O wins the elections in period t, the young individual of period $t-1$ anticipates a tax rate of $\theta_t = 0$. Consequently, the representative young individual anticipates that

[14] This argument abstracts from the knife-edge case that the inefficiencies embodied in $Q(t)$ exactly outweigh the inefficiencies of θ_t^{Ob} or θ_t^{Yb}, respectively.

she completely acquires the rents of both black and green capacity investments in the next period and invests into both technologies. In contrast, if party Y wins the elections in period t, the young individual of period $t-1$ anticipates that the black capacity rent is completely acquired by the government and partly redistributed to the young generation of period t. Consequently, black capacity investments are nil and energy generation completely relies on green technologies.

IV.B. Imperfect foresight

In case of imperfect foresight, the representative individual of the young generation at time $t-1$ expects party O to win the elections in the next period with probability π_t and party Y to win with probability $1-\pi_t$. Because party $i = O, Y$ sets $\theta_t \in \left\{\theta_t^{ib}, \theta_t^{iZ}\right\}$, the expected tax rate Θ_t is determined by one of the four combinations of Tab. 1. However,

	θ_t^{Ob}	θ_t^{OZ}
θ_t^{Yb}	(I)	(II)
θ_t^{YZ}	(III)	(IV)

Table 1: Tax rate combinations

Proposition 4, which is proven in Appendix A.C, rules out the combinations (I) and (III).

Proposition 4 *If the individuals have no perfect foresight and party O wins the elections, it implements a carbon tax rate of $\theta_t = \theta_t^{OZ} = 0 < \min\{\theta_t^{Yb}, \theta_t^{YZ}\}$ and no black capacity becomes a stranded asset.*

The case $\theta_t \in \left\{\theta_t^{Yb}, \theta_t^{Ob}\right\}$ is ruled out, because (19) implies that the black capacity constraint binds if $\theta_t = \min\left\{\theta_t^{Yb}, \theta_t^{Ob}\right\}$. In case of $\theta_t \in \left\{\theta_t^{YZ}, \theta_t^{Ob}\right\}$, the tax rate θ_t^{YZ} is such that the complete black scarcity rent is taxed away. Because the black capacity constraint doesn't bind if party O wins, $\theta_t^{Ob} > \theta_t^{YZ}$. Therefore, the profits from black energy sales (area B in Fig. 2) decrease, more tax revenues per black energy unit are redistributed to the young generation (higher area Θ), and the green scarcity rent (area A) increases. Proposition 4 implies that the last effect, which benefits the old generation, is outweighed by the other two effects. Consequently, party O will implement $\theta_t^{OZ} = 0$ if it wins the elections in period t.

IV.B.1. Case (II): Fossil assets at risk

In contrast, party Y may implement either θ_t^{Yb} or θ_t^{YZ}. In the first case, that is for $\theta_t \in \left\{\theta_t^{Yb}, \theta_t^{OZ}\right\}$, some black capacity becomes stranded if the young party gets elected in period t. In this case, the expected tax rate and energy price are given by $\Theta_t = \pi_t \theta_t^{OZ} + [1-\pi_t]\theta_t^{Yb} = [1-\pi_t]\theta_t^{Yb}$ and $P_t = \pi_t \left\{\beta - \frac{\gamma}{2}\left[Z_t + Q_t\right]\right\} + [1-\pi_t]\left[\frac{2m}{2m+\gamma}\beta + \frac{\gamma}{2m+\gamma}\theta_t^{Yb} - \frac{\gamma m}{2m+\gamma}Q_t\right]$. Substituting into (20) and (21), and solving yield

$$(36)\ Z_t = \frac{\frac{1-\pi_t}{m}\frac{2m+\pi_t\gamma}{4m+\gamma}\left\{\beta - 2[1+\rho\delta]h\right\} + \frac{[\alpha-\sigma_{t-1}]\pi_t - 1}{\rho m}}{\frac{1-\pi_t}{m}\pi_t\frac{\gamma}{2} + 1},$$

$$(37)\ Q_t = \frac{\frac{2}{\gamma}\left[1 - \frac{[1-\pi_t]^2\gamma}{4m+\gamma}\right]\beta + \frac{\pi_t}{\rho m} - [2m+\pi_t\gamma]\frac{\alpha-\sigma_{t-1}}{\rho m\gamma} + 2\frac{1-\pi_t}{m}\frac{2m+\pi_t[2m+\gamma]}{4m+\gamma}\left[1+\rho\delta\right]h}{\frac{1-\pi_t}{m}\pi_t\frac{\gamma}{2} + 1}.$$

The capacities in period t are equal to the investments made in $t-1$. Therefore, (36) and (37) imply that black capacity investments decrease with marginal environmental damages h, while green capacity investments increase with h, which is driven by the expected tax rate Θ_t. The fiercer the environmental problem, the higher the tax rate set by party Y in t and, therefore, the higher the expected tax rate. Consequently, the young generation of $t-1$ expects that it can use the less black capacity in period t the higher h, so that it reduces its black capacity investments. To substitute for the missing energy generating capacity, green capacity investments increase.

Ceteris paribus, (36) and (37) also show that black [green] capacity investments decrease [increase] with the investment subsidy σ_{t-1}. A higher subsidy rate renders green capacity investments less costly, so that they increase in σ_{t-1}. However, the corresponding additional capacity will drive black capacity out of the market in period t implying a reduction of black capacity investments, because the young generation will not invest in what it expects to become a stranded asset.

At first, suppose that party O wins the elections in period t. Then, it implements the tax rate $\theta_t = \theta_t^{oZ} = 0$, so that $b_t^s = Z_t$ and

$$(38)\qquad p_t = \frac{\frac{[1-\pi_t]\gamma\pi_t}{4m+\gamma}\left\{\beta - 2[1+\rho\delta]h\right\} + \frac{\gamma}{2}\frac{1-\pi_t}{\rho m} + \frac{\alpha-\sigma_{t-1}}{\rho}}{\frac{1-\pi_t}{m}\pi_t\frac{\gamma}{2} + 1}$$

hold.[15] Because the tax rate that party Y would like to implement increases in marginal environmental damage h, young individuals of period $t-1$ invest more into green capacity

[15]If $b_t^s \leq Z_t$, we find $b_t^s = \frac{\gamma}{2m+\gamma}\frac{\frac{1-\pi_t}{m}\frac{2m+\pi_t[2m+\gamma]}{4m+\gamma}\{\beta-2[1+\rho\delta]h\}+\pi_t\frac{\alpha-\sigma_{t-1}-1}{\rho m}+2\frac{\alpha-\sigma_{t-1}}{\rho\gamma}}{\frac{1-\pi_t}{m}\pi_t\frac{\gamma}{2}+1}$, which is positive by $\beta > 2[1+\rho\delta]$. The black capacity constraint does not bind if $\beta - 2[1+\rho\delta] > \frac{[4m+\gamma]\{2m[\alpha-\sigma_{t-1}]+\gamma\}}{4\rho m^2} +$

and less into black capacity the higher h. If party O then wins the election at time t, the former effect outweighs the latter with respect to the price p_t, which decreases in h. Ceteris paribus, the positive effect of a higher subsidy on green capacity investments outweighs the negative effect on black capacity investments, so that the total energy generation capacity $Q_t + Z_t$ increases with the subsidy rate explaining the depressing effect of σ_{t-1} on the price at time t.

If party Y wins the elections in period t, it implements the tax rate

$$\theta_t^{Yb} = \frac{\frac{\alpha-\sigma_{t-1}}{\rho} + \pi_t \frac{\gamma}{2} \frac{\alpha-\sigma_{t-1}-1}{\rho m} - \frac{2m+\pi_t\gamma}{4m+\gamma}\left\{\beta - 2\left[1+\rho\delta\right]h\right\}}{\frac{1-\pi_t}{m}\pi_t\frac{\gamma}{2}+1}. \tag{39}$$

The tax rate has straightforward properties. The larger the environmental damages of one additional emission unit the higher the tax rate. Because the young generation of period t also suffers from environmental damages in the next period, the effect is the stronger the lower the natural regeneration rate $(1-\delta)$ and the higher the discount factor ρ. Ceteris paribus, the tax rate is the lower the higher the subsidy rate σ_{t-1}, because of the positive [negative] effect of the subsidy rate on green [black] capacity investments, which alleviates the environmental problem. Substituting (39) into (25) and taking account of (37) yield

$$b_t^s = \frac{2}{4m+\gamma}\left\{\beta - 2\left[1+\rho\delta\right]h\right\}. \tag{40}$$

Unsurprisingly, the same effects of h, ρ, and δ that boost the tax rate lower the use of black energy. However, the subsidy rate σ_{t-1} has no direct effect on black energy supply at time t, because the positive effect of a lower tax rate and the negative effect of a higher green capacity cancel each other out. Finally, the energy price at time t reads

$$p_t = \frac{\frac{\alpha-\sigma_{t-1}}{\rho} + \frac{\pi_t\gamma}{2\rho m}\left[\alpha-\sigma_{t-1}-1\right] - \frac{\gamma\pi_t^2}{4m+\gamma}\left\{\beta - 2[1+\rho\delta]h\right\}}{\frac{1-\pi_t}{m}\pi_t\frac{\gamma}{2}+1}. \tag{41}$$

As in case of an O-government at time t, the energy price decreases with the subsidy rate ceteris paribus, because of the positive effect of σ_{t-1} on total energy capacity. However, higher environmental damages h boost the energy price. This implies that the effect of a higher green capacity is dominated by the combined effects of a lower black capacity and a higher tax rate.

$\frac{4m+\gamma}{2m\rho[1-\pi_t]}$. A positive tax rate θ_t^{Yb} is ensured by $\beta - 2[1+\rho\delta] < \frac{4m+\gamma}{2m+\gamma\pi_t}\left[\frac{\alpha-\sigma_{t-1}}{\rho} + \frac{\gamma}{2}\pi_t\frac{\alpha-\sigma_{t-1}-1}{\rho m}\right]$. Because $\frac{[4m+\gamma]\{2m[\alpha-\sigma_{t-1}]+\gamma\}}{4\rho m^2} + \frac{4m+\gamma}{2m\rho[1-\pi_t]} > \frac{4m+\gamma}{2m+\gamma\pi_t}\left[\frac{\alpha-\sigma_{t-1}}{\rho} + \frac{\gamma}{2}\pi_t\frac{\alpha-\sigma_{t-1}-1}{\rho m}\right]$, our restriction to non-negative tax rates ensures a binding black capacity constraint in case of $\theta_t = \theta_t^{OZ} = 0$.

Lemma 1 *A non-binding black capacity constraint requires*

$$\sigma_{t-1} < \tilde{\sigma}_{t-1} = \alpha - \frac{1}{\pi_t} - \frac{2\rho m\{\beta - 2[1+\rho\delta]h\}}{4m+\gamma}. \tag{42}$$

That is, $\theta_t \in \left\{\theta_t^{Yb}, \theta_t^{OZ}\right\}$ is only possible if the subsidy rate σ_{t-1} was set sufficiently low. Otherwise, the high subsidy rate boosts green investments and depresses black investments sufficiently such that the black capacity constraint binds in period t, i.e. the economy is in case (IV).

IV.B.2. Case (IV): No stranded assets

In case (IV), the black capacity constraint binds no matter which party holds office in period t and no capacities are stranded. Then, $\theta_t \in \left\{\theta_t^{YZ}, \theta_t^{OZ}\right\}$ holds with an expected tax rate of $\Theta_t = [1-\pi_t]\left[\beta - \frac{\gamma}{2}Q_t - \frac{2m+\gamma}{2}Z_t\right]$ and an expected energy price of $P_t = \beta - \frac{\gamma}{2}Q_t - \frac{\gamma}{2}Z_t$. Substituting into (20) and (21), and solving yield

$$Z_t = \frac{\alpha - \sigma_{t-1}}{\rho m} - \frac{1}{\rho m \pi_t}, \tag{43}$$

$$Q_t = \frac{2}{\gamma}\beta - \frac{2m+\gamma}{\gamma}\frac{\alpha - \sigma_{t-1}}{\rho m} + \frac{1}{\rho m \pi_t}. \tag{44}$$

Similar to case (II), the black [green] capacity investments decrease [increase] with the subsidy rate ceteris paribus. If party O wins the elections in t, it implements $\theta_t^{oZ} = 0$. In case that party Y wins, the tax rate is $\theta_t = \frac{1}{\rho \pi_t}$. In both cases the complete black capacity is used in period t and the energy price is

$$p_t = \frac{\alpha - \sigma_{t-1}}{\rho}. \tag{45}$$

Ceteris paribus, a higher subsidy rate decreases the price, because the positive effect of the subsidy on green capacity investments outweighs the negative effect on black capacity investments, so that total energy generation capacity increases.

IV.B.3. Case (II) or Case (IV)

The expectations about the election outcome play a crucial role. If the individuals rather expect party Y to win the elections in period t, i.e. if $\pi_t \to 0$, (42) does not hold and $\theta_t \in \left\{\theta_t^{yZ}, \theta_t^{oZ}\right\}$. In contrast, if π_t is close to unity, individuals rather expect party O to win the elections. Consequently, their black capacity investments are more oriented to a tax rate of zero and, therefore, higher than in case of $\pi_t \to 0$. If party Y then wins, the investments are too high and some black capacities become stranded assets.

Before turning to the analysis of the optimal subsidy rate, we discuss whether case (II) and case (IV) describe stable equilibria. This is the case, if the best option of a Y-government in period t is to implement the tax rate θ_t^{Yb} $\left[\theta_t^{YZ}\right]$ when facing case (II) [(IV)] capacities as given by (36) and (37) [(43) and (44)]. For this purpose, we substitute (36) - (41) and (43) - (45) into (32) and (33) and take account of (13) and (18), so that welfare W_t^{ij} of old and young individuals ($i = o, y$), given that party $j = O, Y$ holds office, can be written as functions depending on $\sigma_{t-1}, \sigma_t^O, \sigma_t^Y, \theta_t^O, \pi_t$, and π_{t+1}.[16] Welfare of the young generation in period t is higher with a the tax rate θ_t^{Yb} than with the tax rate θ_t^{YZ} if

$$\begin{aligned}\Delta^{II} = W_t^{yY}\Big(&Q_t^{II}(\sigma_{t-1},\pi_t), b_t^s(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^{Yb}(\sigma_{t-1},\pi_t), \sigma_t^Y,\\ &Q_{t+1}(\sigma_t^Y,\pi_{t+1}), Z_{t+1}(\sigma_t^Y,\pi_{t+1}), \pi_{t+1}, W_{t+1}^{oO}(\sigma_{t-1}), W_{t+1}^{oY}(\sigma_{t-1})\Big)\\ -W_t^{yY}\Big(&Q_t^{II}(\sigma_{t-1},\pi_t), Z_t^{II}(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^{YZ}(\sigma_{t-1},\pi_t), \sigma_t^Y,\\ &Q_{t+1}(\sigma_t^Y,\pi_{t+1}), Z_{t+1}(\sigma_t^Y,\pi_{t+1}), \pi_{t+1}, W_{t+1}^{oO}(\sigma_{t-1}), W_{t+1}^{oY}(\sigma_{t-1})\Big) > 0\end{aligned} \tag{46}$$

and

$$\begin{aligned}\Delta^{IV} = W_t^{yY}\Big(&Q_t^{IV}(\sigma_{t-1},\pi_t), b_t^s(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^{Yb}(\sigma_{t-1},\pi_t), \sigma_t^Y,\\ &Q_{t+1}(\sigma_t^Y,\pi_{t+1}), Z_{t+1}(\sigma_t^Y,\pi_{t+1}), \pi_{t+1}, W_{t+1}^{oO}(\sigma_{t-1}), W_{t+1}^{oY}(\sigma_{t-1})\Big)\\ -W_t^{yY}\Big(&Q_t^{IV}(\sigma_{t-1},\pi_t), Z_t^{IV}(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^{YZ}(\sigma_{t-1},\pi_t), \sigma_t^Y,\\ &Q_{t+1}(\sigma_t^Y,\pi_{t+1}), Z_{t+1}(\sigma_t^Y,\pi_{t+1}), \pi_{t+1}, W_{t+1}^{oO}(\sigma_{t-1}), W_{t+1}^{oY}(\sigma_{t-1})\Big) > 0\end{aligned} \tag{47}$$

hold, where (Z_t^{II}, Q_t^{II}) and (Z_t^{IV}, Q_t^{IV}) are the capacities as given by (36), (37) and (43), (44), respectively. In Appendix A.D, we prove

Proposition 5 *If party Y holds office in period t, it prefers a case (II) type policy if $\sigma_{t-1} \neq \tilde{\sigma}_{t-1}$ and is indifferent between a case (II) type policy and a case (IV) type policy if $\sigma_{t-1} = \tilde{\sigma}_{t-1}$.*

Proposition 5 has the important implication that party Y, if in office at period t, is never worse off with the tax rate θ_t^{Yb} than with the tax rate θ_t^{YZ}. First, the high tax rate

[16] We get $W_t^{oO}\Big(Q_t(\sigma_{t-1},\pi_t), Z_t(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^O, \sigma_t^O, Q_{t+1}(\sigma_t^O,\pi_{t+1})\Big)$, $W_t^{oY}\Big(Q_t(\sigma_{t-1},\pi_t), b_t^s(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^Y(\sigma_{t-1},\pi_t), \sigma_t^Y, Q_{t+1}(\sigma_t^Y,\pi_{t+1}))\Big)$, $W_t^{yO}\Big(Q_t(\sigma_{t-1},\pi_t), Z_t(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^O, \sigma_t^O, Q_{t+1}(\sigma_t^O,\pi_{t+1})), Z_{t+1}(\sigma_t^O,\pi_{t+1}), \pi_{t+1}, W_{t+1}^{oO}(\sigma_{t-1}), W_{t+1}^{oY}(\sigma_{t-1})\Big)$ and $W_t^{yY}\Big(Q_t(\sigma_{t-1},\pi_t), b_t^s(\sigma_{t-1},\pi_t), p_t(\sigma_{t-1},\pi_t), \theta_t^Y(\sigma_{t-1},\pi_t), \sigma_t^Y, Q_{t+1}(\sigma_t^Y,\pi_{t+1}), Z_{t+1}(\sigma_t^Y,\pi_{t+1}), \pi_{t+1}, W_{t+1}^{oO}(\sigma_{t-1}), W_{t+1}^{oY}(\sigma_{t-1})\Big)$.

θ_t^{Yb} implies that a part of the black capacity Z_t becomes stranded assets, which reduces the CO_2 emissions and, therefore, the climate damages the young generation suffers from in period t and period $t+1$. Second, with some black capacity as stranded assets, there is no black capacity rent (area C in Fig. 2), which would only benefit the old generation. Rather, the rent is taxed away and partly redistributed to the young generation by means of a higher transfer T. Consequently, party Y sets carbon tax θ_t^{Yb} if the subsidy σ_{t-1} falls short of $\tilde{\sigma}_{t-1}$. If the subsidy exceeds $\tilde{\sigma}_{t-1}$, party Y would still prefer the tax rate θ_t^{Yb}. However, the high subsidy has boosted green capacity Q_t, which reduces θ_t^{Yb}, as shown in (35). This lower tax rate is not sufficient to let some black capacity strand, so that party Y is forced to implement the tax rate θ_t^{YZ}. That is, the government of period $t-1$ can bind the hands of a Y-government in period t and restrict it to case (IV) policies by setting a sufficiently high subsidy rate. When this option is used is analyzed in the following.[17]

V. Subsidy

The results of the previous sections allow us to analyze which subsidy rate is set by party Y or O in period $t-1$, which is the last step in our backward induction. At first, suppose that party O holds office in period $t-1$. Because the lifetime of the old generation ends in period $t-1$, the old party is not interested in following periods implying that welfare W_{t-1}^{oO} does not depend on election probabilities. By maximizing W_{t-1}^{oO} with respect to σ_{t-1}, we get

$$(48)\qquad \frac{dW_{t-1}^{oO}}{d\sigma_{t-1}} = -\frac{\sigma_{t-1}}{2}\frac{\partial Q_t}{\partial \sigma_{t-1}} - \frac{Q_t}{2} \leq 0 \qquad\qquad \sigma_{t-1}\frac{dW_{t-1}^{oO}}{d\sigma_{t-1}} = 0.$$

Because $\frac{\partial Q_t}{\partial \sigma_{t-1}}$ is positive for both case (II) and case (IV), the Kuhn-Tucker-condition (48) implies

Proposition 6 *Suppose that party O holds office in $t-1$. It implements the green investment subsidy rate $\sigma_{t-1}^{O} = 0$.*

Subsidizing green investments is not beneficial for the old generation, since the costs of the subsidy are partly born by the old generation but the benefits do not materialize before the generation's end of lifetime. Consequently, party O prefers a subsidy rate of zero.

[17] $Z_t > b_t^s$ also yields (42) if Z_t is given by (43) and b_t^s by $b_t^{s,II,IV}$ as defined in Appendix A.D. Note that there is no need to bind the hands of an O-government, because an O-government doesn't tax carbon.

If party Y holds office in $t-1$, it takes into account that the young generation of $t-1$ will be alive in period t. Consequently, the party's optimization problem depends on the election probability π_t. For the sake of simplicity, we assume at first that π_t is exogenously given but relax this assumption later on.

V.A. Party Y with exogenous election probability

Suppose that the election probability is exogenously given. Party Y maximizes W_{t-1}^{yY} with respect to σ_{t-1}. The corresponding first-order condition reads

$$(49)\quad \frac{dW_{t-1}^{yY}}{d\sigma_{t-1}} = \frac{Q_t}{2} - \left[\alpha - \frac{\sigma_{t-1}}{2}\right]\frac{\partial Q_t}{\partial \sigma_{t-1}} - \frac{\partial Z_t}{\partial \sigma_{t-1}} + \rho\left\{\pi_t \frac{dW_t^{oO}}{d\sigma_{t-1}} + [1-\pi_t]\frac{dW_t^{oY}}{d\sigma_{t-1}}\right\} = 0,$$

where

$$(50)\quad \frac{dW_t^{oO}}{d\sigma_{t-1}} = \frac{Z_t + Q_t}{2}\frac{\partial p_t}{\partial \sigma_{t-1}} + [p_t - mZ_t]\frac{\partial Z_t}{\partial \sigma_{t-1}} + p_t\frac{\partial Q_t}{\partial \sigma_{t-1}} - h\frac{\partial Z_t}{\partial \sigma_{t-1}},$$

$$(51)\quad \begin{aligned}\frac{dW_t^{oY}}{d\sigma_{t-1}} &= \frac{b_t^s + Q_t}{2}\frac{\partial p_t}{\partial \sigma_{t-1}} + [p_t - mb_t^s - \theta_t]\frac{\partial b_t^s}{\partial \sigma_{t-1}} - \frac{b_t^s}{2}\frac{\partial \theta_t}{\partial \sigma_{t-1}} \\ &\quad + p_t\frac{\partial Q_t}{\partial \sigma_{t-1}} + \frac{\theta_t}{2}\frac{\partial b_t^s}{\partial \sigma_{t-1}} - h\frac{\partial b_t^s}{\partial \sigma_{t-1}}.\end{aligned}$$

According to (49), the optimal subsidy rate equates the marginal benefits of a higher subsidy with the marginal costs. The marginal benefits of period $t-1$ are given by higher net grants for capacity investments, reflected by the first term of (49) and a reduction of black capacity investment costs ($\partial Z_t/\partial \sigma_{t-1} < 0$). The marginal costs of period $t-1$ are given by higher green capacity investments ($\partial Q_t/\partial \sigma_{t-1} > 0$). With respect to period t, party Y considers the expected marginal effect of a higher subsidy rate. If the young generation of period $t-1$ remains in power in period t, the marginal effect is given by $\frac{dW_t^{oO}}{d\sigma_{t-1}}$ and by $\frac{dW_t^{oY}}{d\sigma_{t-1}}$ otherwise. In the former case, the first term of (50) reflects the price effect of a higher subsidy rate on the net revenues from energy sales. The second and third term are the energy production effects. Finally, the last term indicates the environmental effect, i.e. that a higher subsidy reduces black capacity investments and, therefore, climate damages. In case that the party representing the young generation of period t wins the election at period t, the three effects are supplemented by two tax effects. First, the third term of (51) indicates the change of net tax payments caused by a change of the tax rate. Second, the fifth term represents the change of tax refunds caused by a changing black energy production. The tax terms are missing in (50), because an O-government will implement the tax rate $\theta_t^{OZ} = 0$ at time t.

Suppose that the economy is in case (II), i.e. that (42) holds. Then, we find that a higher subsidy depresses the energy price p_t, so that the price effects are negative. If party Y holds office in period t, black energy supply b_t^s is not affected by the subsidy rate σ_{t-1}, while the tax rate θ_t decreases with the subsidy. Thus, the black energy production effect, the second tax effect and, in particular, the environmental effect of (51) vanish. By solving (49), we get

Proposition 7 *Suppose that party Y holds office in $t-1$ and that the election probability is exogenous. If party Y follows a case (II) type policy, it implements the green investment subsidy*

$$\begin{aligned}\sigma_{t-1}^{II} = {} & \frac{2\gamma\pi_t}{4m^2 + 4m\gamma[1-\pi_t]^2\pi_t + \gamma^2\pi_t^2[1-\pi_t]}\Bigg\{ m[3-2\pi_t][1-\alpha\pi_t] \\ & - \rho m[1-\pi_t]\frac{2m[1-2\pi_t]+\pi_t\gamma}{4m+\gamma}\Big[\beta - 2[1+\rho\delta]h\Big] \\ & + \rho\pi_t h\Big[2m + \pi_t\gamma[1-\pi_t]\Big]\Bigg\}. \end{aligned} \tag{52}$$

The opposing signs of the terms in curly brackets reflect the opposing effects discussed above. In particular, if party Y holds office in period $t-1$, it faces opposing effects of marginal climate damages h, because the climate damage parameter directly influences the equilibrium of period t. For example, (37) shows that the green capacity investments are the higher the more serious the environmental problem. Furthermore, the energy price p_t increases with h if party Y holds office in period t. Consequently, revenues from green energy sales in period t are boosted. On the other hand, (36) shows that black capacity investments are the lower the higher marginal climate damages. Given an O-government in period t, also the energy price p_t decreases in h. Both lead to lower revenues from black energy sales. Which effects dominate, i.e. whether σ_{t-1}^{II} increases or decreases with h, depends on the election probability π_t. If $\pi_t < \frac{2m}{4m-\gamma}$, the positive effects dominate, so that the subsidy rate increases with marginal climate damages.

Consider now case (IV). No matter if party Y or O is in power in period t, the price p_t decreases with the subsidy rate, while the tax rate of period t is independent from the subsidy rate. Because all black capacity is used in case (IV), the environmental effect in both (50) and (51) is positive. Solving (49) yields

Proposition 8 *Suppose that party Y holds office in $t-1$ and that the election probability is exogenous. If party Y follows a case (IV) type policy, it implements the green investment subsidy*

$$\sigma_{t-1}^{IV} = \frac{\gamma\,[1-\alpha+2\rho h]}{2m}. \tag{53}$$

In contrast to case (II), the optimal subsidy rate unambiguously increases with the environmental damage parameter h. The reason is that capacities, the energy price p_t and the tax rates θ_t^{YZ} and θ_t^{OZ} are independent from the climate damage parameter in case (IV). Consequently, a higher h has no direct effects on a case (IV) equilibrium in period t. However, the binding black capacity constraint implies that in period $t-1$ a Y-government can reduce future climate damages by increasing the subsidy rate, which reduces black capacity investments. The higher marginal climate damages h, the more a Y-government will use this channel.

Whether a Y-government should choose σ_{t-1}^{II} or σ_{t-1}^{IV} depends on the parameters of the model. In Appendix A.E, we prove Proposition 9.

Proposition 9 *Suppose that party Y holds office in $t-1$ and that the election probability is exogenous.*
(i) If $\alpha \in [\max\{\alpha^{\min II}, \alpha^{\Delta II}\}, \alpha^{II}]$, the subsidy rate σ_{t-1}^{II} is feasible.
(ii) If $\alpha \in [\alpha^{\min IV}, \min\{\alpha^{IV}, \alpha^{\Delta IV}\}]$, the subsidy rate σ_{t-1}^{IV} is feasible.
(iii) If the two parameter spaces from (i) and (ii) overlap, σ_{t-1}^{II} is only superior to σ_{t-1}^{IV}, if $\alpha \leq \tilde{\alpha}$.
The thresholds are given by

$$\alpha^{\min II} = \frac{1}{\pi_t} + \frac{2\rho m\{\beta - 2[1+\rho\delta]h\}}{4m+\gamma},$$

$$\alpha^{\min IV} = 1 + \frac{2\rho\gamma h}{2m+\gamma},$$

$$\alpha^{II} = \alpha^{\min II} + \frac{2\rho m + \rho\gamma\pi_t[1-\pi_t]}{3-2\pi_t}\left\{\frac{h}{m} - \frac{\beta - 2[1+\rho\delta]h}{\pi_t[4m+\gamma]}\right\}$$

$$\alpha^{\Delta II} = \alpha^{\min II} - \frac{2\rho\gamma\pi_t}{2m+\gamma\pi_t}\left\{\frac{m[\beta - 2[1+\rho\delta]h]}{4m+\gamma} - \pi_t h\right\}$$

$$\alpha^{IV} = 1 + 2\rho h$$

$$\alpha^{\Delta IV} = \alpha^{\min II} + \frac{2\rho\gamma h}{2m+\gamma} - \frac{\gamma[1-\pi_t]}{[2m+\gamma]\pi_t} - \frac{\gamma}{2m+\gamma}\frac{2\rho m\{\beta - 2[1+\rho\delta]h\}}{4m+\gamma},$$

$$\tilde{\alpha} = \frac{1}{[4m+\gamma]^2\pi_t\left\{4m[4m+\gamma]\left[m+[m+\gamma]\pi_t[1-\pi_t]\right] + \gamma\pi_t^2[\gamma[4m+\gamma]+8m^2]\right\}}$$
$$\Bigg\{2\Bigg[m^2[4m+\gamma]^2\Big[4m^2 + 4m\gamma\pi_t[1-\pi_t]^2 + \gamma^2\pi_t^2[1-\pi_t]\Big]\Big[[4m+\gamma][2m+\gamma\pi_t]$$
$$- 2\rho h\pi_t[4m+\gamma][\gamma\pi_t + 2m[1+\pi_t]] + 4\rho m^2\pi_t[\beta - 2[1+\rho\delta]h]\Big]^2\Bigg]^{0.5}$$
$$+ [4m+\gamma]\Bigg[[2m+\gamma]\gamma^3\pi_t^3[1+2\rho h] + 2m\gamma^3\pi_t^2[3+4\rho h]$$
$$+ 16m^4\Big[2 + 4\pi_t[1-\pi_t] + \pi_t[\rho + 2\rho\pi_t[1-\pi_t]][\beta - 2[1+\rho\delta]h] + 4\rho h\pi_t[1+\pi_t]\Big]\Bigg]$$
$$+ 8[4m+\gamma]m^3\gamma\Big[1 + 4\pi[2-\pi_t^2] + 6\rho h\pi_t[1+\pi_t] + \pi_t^2\Big[4\rho h[2-\pi_t]$$

$$+ \rho[2-\pi_t][\beta - 2[1+\rho\delta]h]\Big]\Big] + 4[4m+\gamma]m^2\gamma^2\pi_t\Big[3[1+\pi_t]$$

$$+ 2\rho h[1+\pi_t] + 4\pi_t[1-\pi_t] + 6\rho h\pi_t[2-\pi_t] + \rho\pi_t^2\Big[\beta - 2[1+\rho\delta]h\Big]\Big]\Big\}.$$

To understand Proposition 9, suppose that both π_t and $\beta - 2[1+\rho\delta]h$ are small. Then, it can be shown that $0 < \alpha^{\min IV} < \alpha^{IV} < \alpha^{\Delta IV} < \alpha^{\min II} < \alpha^{\Delta II} < \alpha^{II}$ holds, which allows us to illustrate the evolution of the subsidy rate σ_{t-1} dependent on α as in Fig. 3.[18] The

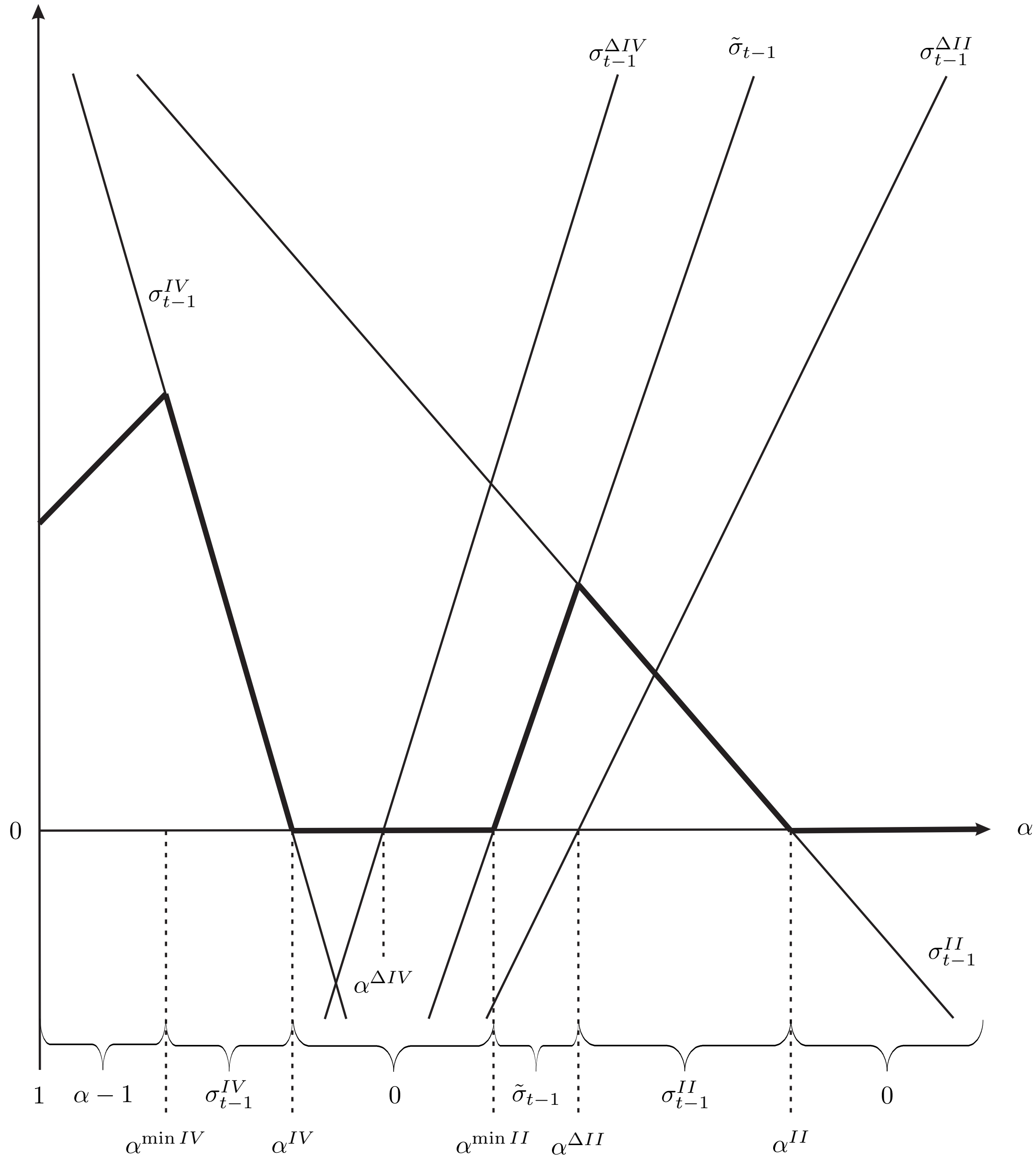

Figure 3: The optimal subsidy rate depending on α

σ^{II}_{t-1}, σ^{IV}_{t-1} and $\tilde{\sigma}_{t-1}$ curves illustrate the linear relationship between σ^{II}_{t-1}, σ^{IV}_{t-1}, $\tilde{\sigma}_{t-1}$ and

[18]See Appendix 9.

α. The differences $\sigma_{t-1}^{\Delta II} = \tilde{\sigma}_{t-1} - \sigma_{t-1}^{II}$ and $\sigma_{t-1}^{\Delta IV} = \tilde{\sigma}_{t-1} - \sigma_{t-1}^{IV}$ also linearly depend on α and are illustrated by the corresponding curves. The subsidy σ_{t-1}^{II} can be only set if it is positive and falls short of $\tilde{\sigma}_{t-1}$. The former implies $\alpha < \alpha^{II}$ and the latter $\alpha > \alpha^{\Delta II}$. Finally, $\tilde{\sigma}_{t-1} > 0$ yields $\alpha^{\min II}$. In case of the subsidy σ_{t-1}^{IV}, the difference $\sigma_{t-1}^{\Delta IV}$ needs to be negative and the subsidy rate positive, which gives $\min\{\alpha^{IV}, \alpha^{\Delta IV}\}$ as upper limit for the parameter space allowing for σ_{t-1}^{IV}. The lower limit $\alpha^{\min IV}$ is given by the requirement that σ_{t-1}^{IV} falls short of $\alpha - 1$.[19]

Because of the small π_t, the Y-government of period $t-1$ expects to lose the next elections with a high probability. According to Proposition 5, the probable successor prefers a case (II) type policy, so that there is a high risk that some black capacity investments made in $t-1$ end up as stranded assets. This implies a high incentive for the Y-government to influence the next government in a way that reduces the carbon tax set in period t, i.e. the Y-government wants to bind the hands of its successor.

If α is close to unity, i.e. if green capacity investments are cheap, the Y-government can avoid the risk of stranded assets by granting a subsidy $\sigma_{t-1} \to \alpha - 1$, which (almost) equates the costs of black and green capacity investments ensuring a reallocation of all investments to green capacity. This is beneficial for the young generation of period $t-1$ for two additional reasons. First, without a black capacity, there are no additional climate damages and no extraction costs in the next period. Second, the profits of clean energy production in period t belong completely to the young generation of $t-1$, while half of the subsidy costs are born by the old generation. The higher α, i.e. the more expensive green capacity investments, the higher the subsidy rate $\sigma_{t-1} \to \alpha - 1$. At $\alpha^{\min IV}$, the high subsidy costs are no longer optimal and the optimal subsidy policy switches to the σ_{t-1}^{IV} regime. With this regime, the Y-government of period $t-1$ ensures that its successor either sets $\theta_t = 0$ (if the elections are won) or $\theta_t = \theta_t^{YZ}$ (if the elections are lost) implying that the complete black capacity is used in period t. Thus, the Y-government can successfully bind the hand of the next government. Under the σ_{t-1}^{IV} regime, higher green capacity costs lead to a lower subsidy. That is, it becomes increasingly beneficial for the young generation of period $t-1$ to avoid high green capacity investments but to bear the additional climate damages and extraction costs in the following period. At α^{IV}, this incentive becomes so strong that the Y-government would prefer a negative subsidy. Because this is ruled out

[19] Note that $\tilde{\sigma}_{t-1} < \alpha - 1$ holds, so that $\sigma_{t-1}^{II} < \tilde{\sigma}_{t-1}$ implies $\sigma_{t-1}^{II} < \alpha - 1$.

by assumption, the subsidy level remains nil for all $\alpha \in [\alpha^{IV}, \alpha^{\min II})$. However, note that this zero subsidy still exceeds the critical value $\tilde{\sigma}_{t-1}$ and is, therefore, sufficient to bind the hands of the government of period t. At $\alpha^{\min II}$, the optimal subsidy policy switches into the $\tilde{\sigma}_{t-1}$ regime. The reason is that the young generation of period $t-1$ can no longer expect to be in a case (IV) situation with a subsidy rate of zero if its party loses the elections in period t. Rather, in period t, a Y-government will implement a case (II) policy, because $0 < \tilde{\sigma}_{t-1}$. To bind the hands of such a government, the Y-government of period $t-1$ grants the smallest subsidy ensuring that there will be no stranded assets in the next period. With more expensive green capacity investments, the subsidy rate $\tilde{\sigma}_{t-1}$ increases to counter the incentive of more black capacity investments. At $\alpha^{\Delta II}$, the optimal case (II) subsidy rate σ_{t-1}^{II} becomes feasible. That is, for $\alpha > \alpha^{\Delta II}$ it is no longer optimal for the Y-government of period $t-1$ to fully bind its successors hands but to accept that some black capacity investments will strand in period t if the elections are lost. To reduce the amount of possibly stranded black capacity, the subsidy rate σ_{t-1}^{II} is granted. As in case of σ_{t-1}^{IV}, higher green capacity investments costs reduce the subsidy and imply a subsidy rate of zero for all $\alpha \geq \alpha^{II}$.

If the assumption of a small election probability π_t does not hold, the parameter spaces allowing for σ_{t-1}^{II} and σ_{t-1}^{IV} may overlap. In this case, the Y-government of period $t-1$ will choose the subsidy rate which maximizes welfare. The corresponding welfare difference $W_{t-1}^{yY}(\sigma_{t-1}^{II}) - W_{t-1}^{yY}(\sigma_{t-1}^{IV})$ describes a parabola open downwards with the zeros at $\alpha = \pm\tilde{\alpha}$, so that σ_{t-1}^{II} will be chosen if $\alpha < \tilde{\alpha}$. It is noteworthy that cheap green capacity investments now imply the subsidy rate σ_{t-1}^{II}, while the opposite is true for a small election probability π_t. To rationalize this recall that black capacity investments are low in case of a small α. Together with the Y-government's high probability of winning the next elections, this implies that black capacity investments are not at a high risk to become stranded. Consequently, the Y-government has only small incentives to bind the hands of its successor and grants only the small subsidy rate σ_{t-1}^{II}. However, if green capacity investments are expensive, more black capacity investments are at risk, so that the Y-governments opts for the σ_{t-1}^{IV} subsidy rate, which ensures that there are no stranded assets in period t.

V.B. Party Y with endogenous election probability

In this section, we relax the assumption of a fixed election probability. Thus, we assume that the probability π_t is given by (11) and is, therefore, subject to the different welfare functions that may emerge in period t. These functions depend on the subsidy rate σ_{t-1} and the election probability π_t constituting[20]

$$\pi_t = \pi_t(\sigma_{t-1}). \tag{54}$$

By substituting into (33) for period $t-1$ and maximizing with respect to σ_{t-1}, we can determine the preferred subsidy rate. For this purpose, it is useful to rewrite (11) as

$$\pi_t = \frac{\nu}{2}\left(\Delta W_t^{OY}(\sigma_{t-1}, \pi_t)\right) + \frac{1}{2}, \tag{55}$$

with

$$\Delta W_t^{OY}(\sigma_{t-1}, \pi_t) := \left[W_t^{oO}(\sigma_{t-1}, \pi_t) + W_t^{yO}(\sigma_{t-1}, \pi_t)\right] - \left[W_t^{oY}(\sigma_{t-1}, \pi_t) + W_t^{yY}(\sigma_{t-1}, \pi_t)\right]$$

as the welfare difference at time t between an O-government and a Y-government. By differentiating with respect to the subsidy rate, we find

$$\frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}} = \frac{\frac{\nu}{2}\frac{\partial \Delta W_t^{OY}(\sigma_{t-1},\pi_t)}{\partial \sigma_{t-1}}}{1 - \frac{\nu}{2}\frac{\partial \Delta W_t^{OY}(\sigma_{t-1},\pi_t)}{\partial \pi_t}}. \tag{56}$$

If the welfare difference increases with both the subsidy rate and the election probability and is [in]sensitive with respect to the latter, a ruling party Y can increase the chances of its generation to also form the government in period t by lowering [increasing] the subsidy rate. To determine the sign of (56), we differentiate between the cases (II) and (IV).

At first, consider case (IV). No matter which party is in power at period t, the capacities Q_t and Z_t are completely used and the energy price is given by (45). Therefore, also energy consumption of the two generations and emissions are not affected by the government. Therefore, the welfare difference ΔW_t^{OY} can be rewritten as

$$\Delta W_t^{OY,IV}(\sigma_{t-1}, \pi_t) = \alpha[q_t^Y - q_t^O] + [z_t^Y - z_t^O] + \rho \Delta W_{t+1}^O,$$

with

$$\Delta W_{t+1}^O = \left[\pi_{t+1} W_{t+1}^{oO} + [1-\pi_{t+1}] W_{t+1}^{oY}\right]_O - \left[\pi_{t+1} W_{t+1}^{oO} + [1-\pi_{t+1}] W_{t+1}^{oY}\right]_Y$$

[20]See Footnote 16.

as the difference between the expected welfare of the old generation in period $t+1$ given that either party O or party Y holds office in period t. Because the investments q_t and z_t of period t and ΔW^O_{t+1} do not depend on the subsidies of period $t-1$, the numerator of (56) is zero implying

Proposition 10 *Suppose that party Y holds office in $t-1$ and that the election probability is endogenous. If party Y follows a case (IV) type policy, the election probability cannot be influenced by the subsidy rate and Proposition 8 holds.*

In case (II), $\frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}}$ can be positive or negative. Consequently, party Y takes into account that it can manipulate π_t by setting its subsidy level σ_{t-1}. Thus, the first order condition for maximizing W^{yY}_{t-1} with respect to σ_{t-1} (which is given by (49) for exogenous election probabilities) becomes

$$
\begin{aligned}
\frac{\mathrm{d}W^{yY}_{t-1}}{\mathrm{d}\sigma_{t-1}} = \frac{Q_t}{2} - \left[\alpha - \frac{\sigma_{t-1}}{2}\right]\left(\frac{\partial Q_t}{\partial \sigma_{t-1}} + \frac{\partial Q_t}{\partial \pi_t}\frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}}\right) \\
- \left(\frac{\partial Z_t}{\partial \sigma_{t-1}} + \frac{\partial Z_t}{\partial \pi_t}\frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}}\right) + \rho\Bigg\{\pi_t\frac{\partial W^{oO}_t}{\partial \sigma_{t-1}} + [1-\pi_t]\frac{\partial W^{oY}_t}{\partial \sigma_{t-1}} \\
+ \frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}}\left([W^{oO}_t - W^{oY}_t] + \pi_t\frac{\partial W^{oO}_t}{\partial \pi_t} + [1-\pi_t]\frac{\partial W^{oY}_t}{\partial \pi_t}\right)\Bigg\} = 0
\end{aligned}
\tag{57}
$$

The closed-form expression of $\frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}}$ is cumbersome and therefore delegated to Appendix A.F. Depending on the parameters of the model, it can be positive or negative. This implies, that following (57), party Y uses the subsidy to influence the elections in the following period and therefore deviates strategically from the subsidy with fixed election probabilities which is given by (52). To shed more light on the strategic behavior we make use of a numerical example, with the parameters listed in Tab. 2.

Parameter	Value
β	85
γ	0.005
m	0.009
ρ	0.8
δ	0.5
α	10
h	25
ν	0.0000055
E_0	0
L	2,000,000

Table 2: Parameter values for the numerical example

We find that a Y-government grants a subsidy of $\sigma_{t-1}^s = 2.55645$ leading to a reelection probability of $\pi_t^s = 0.595826$. In contrast, an O-government sets a subsidy rate of nil leading to $\tilde{\pi}_t^s = 0.573172$. If a Y-government faces an exogenous reelection probability of $\tilde{\pi}_t^s = 0.573172$, it chooses a subsidy rate of $\breve{\sigma}_{t-1} = 2.33646$. Thus, when moving from an exogenous reelection probability to an endogenous one, the strategic considerations induce a Y-government to increase the subsidy rate by 9.42% to boost its reelection probability by 2.27 percentage points. To rationalize the result, recall that party Y of period $t-1$ will represent the old generation in period t. According to (11), the party has two channels to increase its vote share in period t. It can either increase the losses of its generation if the elections will be lost or decrease the losses of the other generation if the elections will be won. Our results suggest that the young party uses the first channel. That is, with an exogenous election probability of $\tilde{\pi}_t^s$, the old generation of period t will lose 3.9% of its welfare if the elections are lost. With an endogenous election probability, the welfare loss amounts to 4.4%. In contrast, the welfare of the young generation of period t increases by 0.04% or 0.06%, respectively, if its party wins the elections.[21] Thus, the old generation of period t has more to lose and the young generation more to win.

To identify the main driving force, we break down the welfare difference of the old generation in several parts. When moving from exogenous to endogenous election probability, both the utility difference and the climate damage difference between a Y-government and an O-government slightly decrease, while the difference of net costs of energy consumption increases. The main driving force is the transfer difference, i.e. the difference of the climate policy costs, which increases considerably.[22] By increasing the subsidy, the Y-government of period $t-1$ ensures that green capacity is increased and black capacity decreased. On the one hand, this implies that less black capacity strands if the elections are lost, which reduces uncertainty with respect to energy supply, consumption and climate damages. On the other hand, a lower black capacity implies a higher energy price if the elections are won, which boosts the profits from energy supply and, therefore,

[21]Because of high income, welfare of the young generation is high, which implies a small relative impact of elections. However, also the absolute welfare difference is considerably smaller than for the old generation.

[22]The utility difference is given by $U(b_t^{oY} + g_t^{oY}) - U(b_t^{oO} + g_t^{oO})$, the difference of net energy costs by $\left[p_{bt}^Y b_t^{sY} - M(b_t^{sY}) - \theta_t b_t^{sY} + p_g^Y g_t^{sY} - p_b^Y b_t^{oY} - p_g^Y g_t^{oY}\right] - \left[p_{bt}^O b_t^{sO} - M(b_t^{sO}) + p_g^O g_t^{sO} - p_b^O b_t^{oO} - p_g^O g_t^{oO}\right]$, and the climate damage difference by $-hE_t^Y + hE_t^O$. Because an O-government does not implement a climate policy, the transfer difference reads $\frac{T^Y}{2}$.

increases the net energy costs difference. Finally, a Y-government at period t faces an identical problem as the Y-government of period $t-1$. Consequently, the individuals that turn old in period t have to bear increased costs of climate policy, if their party loses the elections in t. Because this effect dominates, it increases the incentive for these individuals to vote for their party. To summarize, with an endogenous election probability, we find that the subsidy increases and that both generations have more to lose in elections. In other words, the polarization between generations increases with an endogenous election probability.

VI. Conclusion

In this paper, we study the interaction of climate policies and investments into fossil and renewable energy generation capacities if the policies are set by democratically elected governments. In an overlapping generations model individuals invest into black and green energy generation capacity of the next period. Elections are held in every period to determine climate policies, i.e. a carbon tax and a green investment subsidy, where the parties represent the interest of the young generation (Y) and the old generation (O), respectively. Climate policies are used for two purposes, the redistribution of income between generations and the internalization of climate damages. To avoid income redistribution in favor of the young generation, an O-government will always abstain from climate policies. In contrast, a Y-government offers non-negative tax and subsidy rates.

The carbon tax set by a Y-government causes asset stranding if uncertain elections lead to policy risk and the individuals expect party O to win the elections with a high probability but party Y wins. Then, the individuals aligned their investments to a low expected carbon tax but face a high realized tax after the elections. It is noteworthy that a Y-government always prefers stranding some black capacity. If no assets become stranded, the carbon tax is used for redistribution, and is either equal to zero (O-government) or equal to the black scarcity rent (Y-government). In particular, this result occurs if the individuals have perfect foresight with respect to the election outcome. Then, there is either no or prohibitive carbon taxation and energy generation completely relies on renewables in the latter case.

Governments can avoid asset stranding in the following period by setting a sufficiently high green investment subsidy. This leads to low black capacity investments and in turn binds the hands of a potentially elected Y-government that then chooses a sufficiently low carbon tax allowing all capacity to be used. We show that O-governments never choose this option. With an exogenously given election probability, the subsidy rate set by a Y-government depends on the severity of environmental damages, the costs of green capacity investments and its reelection probability. If environmental damages are high, the reelection probability is small and green investment costs low, the Y-government binds the hands of its successor.

The green investment subsidy can be used to influence the election outcome of the next period. An O-government will not make use of this opportunity, because the current old generation will not be alive in the next period. In contrast, party Y will use the subsidy in a strategic way. Our results suggest that a Y-government sets a higher subsidy than with an exogenous election probability. This increases the potential losses of the current young generation if the elections in the next period will be lost, which induces the individuals of this generation to vote for their party implying an increased reelection probability.

Our analysis can be extended in several directions. Population growth will affect the relative size of generations and, therefore, the election probability. If capacities are not completely depreciated within one period, the evolution of the economy will become path-dependent affecting the decision problems of every period. Finally, the redistribution motive will be affected if only a fraction of the young generation invests into energy generation capacity. We leave these extensions for further research.

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A. Appendix

A.A. Preferred tax rates

Differentiating (32) with respect to θ_t yields

$$\frac{\partial W^{oO}}{\partial \theta_t} = \frac{dp_t}{d\theta_t} b_t^s - b_t^s + \frac{dp_t}{d\theta_t} Q_t + \frac{1}{2}\left[\theta_t \frac{db_t^s}{d\theta_t} + b_t^s\right] - [b_t^o + g_t^o]\frac{dp_t}{d\theta_t} - h\frac{db_t^s}{d\theta_t}.$$

If the black capacity constraint does not bind, we set $\frac{\partial W^{oO}}{\partial \theta_t} = 0$ and substitute $\frac{dp_t}{d\theta_t} = \frac{\gamma}{2m+\gamma}$, $\frac{db_t^s}{d\theta_t} = -\frac{2}{2m+\gamma}$, $b_t^s = \frac{2\beta - 2\theta_t - \gamma Q_t}{2m+\gamma}$, and $b_t^o + g_t^o = \frac{\beta}{\gamma} - \frac{1}{\gamma}\left[\frac{2m\beta+\gamma\theta_t}{2m+\gamma} - \frac{\gamma m Q_t}{2m+\gamma}\right]$ to get the first line of (34). If the black capacity constraint binds, $\frac{dp_t}{d\theta_t} = \frac{db_t^s}{d\theta_t} = 0$ and $b_t^s = Z_t$, so that $\frac{dW^{oO}}{d\theta_t} = -\frac{Z_t}{2} < 0$ implying $\theta_t^o = 0$.

Differentiating (33) with respect to θ_t yields

$$\frac{\partial W^{yY}}{\partial \theta_t} = \frac{b_t^s}{2} + \frac{\theta_t}{2}\frac{db_t^s}{d\theta_t} - [b_t^y + g_t^y]\frac{dp_t}{d\theta_t} - [1+\rho\delta]h\frac{db_t^s}{d\theta_t}.$$

If the black capacity constraint does not bind, we set $\frac{\partial W^{yY}}{\partial \theta_t} = 0$ and substitute $\frac{dp_t}{d\theta_t} = \frac{\gamma}{2m+\gamma}$, $\frac{db_t^s}{d\theta_t} = -\frac{2}{2m+\gamma}$, $b_t^s = \frac{2\beta - 2\theta_t - \gamma Q_t}{2m+\gamma}$, and $b_t^y + g_t^y = \frac{\beta}{\gamma} - \frac{1}{\gamma}\left[\frac{2m\beta+\gamma\theta_t}{2m+\gamma} - \frac{\gamma m Q_t}{2m+\gamma}\right]$ to get the first line of (35). If the black capacity constraint binds, $\frac{dp_t}{d\theta_t} = \frac{db_t^s}{d\theta_t} = 0$ and $b_t^s = Z_t$, so that $\frac{dW^{yY}}{d\theta_t} = \frac{Z_t}{2} > 0$. Thus, the preferred tax rate is set to its maximal level ensuring $b_t^s = Z_t$. According to (14) and (24), θ_t^y is set such that $\lambda_b(t) = 0$ just holds implying $\theta_t^y = -\frac{\gamma}{2}Q_t - \frac{2m+\gamma}{2}Z_t + \beta$.

A.B. Perfect foresight

Suppose that party O wins the elections and implements the tax rate for the non-binding capacity constraint $\theta_t = \theta_t^{ob} = \frac{4m+\gamma}{2}Q_t + \frac{4m+2\gamma}{\gamma}h - \frac{2m\beta}{\gamma}$. Substituting into (21) yields

$$Z_t = \frac{\alpha - \sigma_{t-1} - 1}{\rho m} - \frac{4m+\gamma}{2m}Q_t - \frac{4m+2\gamma}{m\gamma}h + \frac{2}{\gamma}\beta. \tag{A.1}$$

From (20), (24), (25), and (34) we get

$$Q_t = \frac{2}{\gamma}\frac{\alpha - \sigma_{t-1}}{\rho} - \frac{4}{\gamma}h, \tag{A.2}$$

$$b_t^s = \frac{2}{\gamma}\beta - 2Q_t - \frac{4}{\gamma}h. \tag{A.3}$$

Solving (A.1) - (A.3) yields

$$Z_t = \frac{2}{\gamma}\beta + \frac{4}{\gamma}h - \frac{4m[\alpha - \sigma_{t-1} + \gamma}{\rho m\gamma}, \tag{A.4}$$

(A.5) $$b_t^s = \frac{2}{\gamma}\beta + \frac{4}{\gamma}h - \frac{4}{\gamma}\frac{\alpha - \sigma_{t-1}}{\rho},$$

so that $Z_t - b_t^s < 0$. Because the representative young individual of period $t-1$ has perfect foresight, she anticipates that the capacity constraint will bind in the next period ruling out $\theta_t^{ob} = \frac{4m+\gamma}{2}Q_t + \frac{4m+2\gamma}{\gamma}h - \frac{2m\beta}{\gamma}$. Consequently, $\theta_t = \theta_t^{oZ} = 0$ implying

(A.6) $$Z_t = \frac{\alpha - \sigma_{t-1} - 1}{\rho m},$$

(A.7) $$Q_t = \frac{2}{\gamma}\beta + \frac{1}{\rho m} - \frac{2m+\gamma}{\gamma}\frac{\alpha - \sigma_{t-1}}{\rho m}.$$

Suppose that party Y wins the elections and implements the tax rate for the non-binding capacity constraint $\theta_t = \theta_t^y = -\frac{\gamma}{2}Q_t + \frac{4m+2\gamma}{4m+\gamma}[1+\rho\delta]h + \frac{2m\beta}{4m+\gamma}$. Substituting into (21) yields

(A.8) $$Z_t = \frac{\alpha - 1}{\rho m} + \frac{\gamma}{2m}Q_t - \frac{4m+2\gamma}{4m+\gamma}\frac{1+\rho\delta}{m}h - \frac{2}{4m+\gamma}\beta.$$

From (20), (24), (25), and (34) we get

(A.9) $$Q_t = \frac{2}{\gamma}\frac{4m}{4m+\gamma}\beta + \frac{4}{4m+\gamma}[1+\rho\delta]h - \frac{2}{\gamma}\frac{\alpha - \sigma_{t-1}}{\rho},$$

(A.10) $$b_t^s = \frac{2}{4m+\gamma}\beta - \frac{4}{4m+\gamma}[1+\rho\delta]h.$$

Solving (A.8) - (A.10) yields

(A.11) $$Z_t = -\frac{1}{\rho m} + \frac{2}{4m+\gamma}\beta - \frac{4}{4m+\gamma}[1+\rho\delta]h,$$

so that $Z_t - b_t^s < 0$. Because the representative young individual of period $t-1$ has perfect foresight, she anticipates that the capacity constraint will bind in the next period ruling out $\theta_t^{yb} = -\frac{\gamma}{2}Q_t + \frac{4m+2\gamma}{4m+\gamma}[1+\rho\delta]h + \frac{2m\beta}{4m+\gamma}$. Consequently, $\theta_t = \theta_t^{yZ} = \beta - \frac{\gamma}{2}[Q_t + Z_t] - mZ_t$. Substituting into (19) shows that the marginal profits from black capacity investments are nil and, therefore, $Z_t = 0$. Consequently, (20) and (24) imply

$$Q_t = \frac{2}{\gamma}\left[\beta - \frac{\alpha - \sigma_{t-1}}{\rho}\right].$$

□

A.C. Imperfect foresight

The tax rate is either θ_t^{ob} or θ_t^{oZ} if party O wins and either θ_t^{yb} or θ_t^{yZ} if party Y wins. Thus, the expected tax rate is given by one of the four combinations of Tab. 1.

Consider combination (I). Then, either $\theta_t = \theta_t^{ob}$ or $\theta_t = \theta_t^{yb}$ and $\Theta_t = \pi_t \theta_t^{ob} + [1-\pi_t]\theta_t^{yb}$. Suppose $\theta_t^{ob} > \theta_t^{yb}$. Then, the young generation invests less than in case of party Y's certain election but more than in case of party O's certain election. From (19) we known that with perfect foresight the young generation's black capacity investments are too small to ensure $b_t^s < Z_t$. Consequently, if party Y wins, the black capacity will not be large enough to allow party Y to implement θ_t^{yb}, so that $\theta_t = \theta_t^{yZ}$ and $b_t^s = Z_t$. For the case $\theta_t^{ob} < \theta_t^{yb}$, an analogous argument implies that party O implements θ_t^{oZ} if it wins. Thus, combination (I) can be ruled out.

Consider combination (III). The expected tax rate is given by

$$\Theta_t = \pi_t \left[\frac{4m+\gamma}{2} Q_t + \frac{2(2m+\gamma)}{\gamma} h - \frac{2m}{\gamma}\beta \right] + [1-\pi_t] \left[\beta - \frac{\gamma}{2} Q_t - \frac{2m+\gamma}{2} Z_t \right],$$

while the expected price at time t reads

$$P_t = \pi_t \left[\frac{\gamma}{2} Q_t + 2h \right] + [1-\pi_t] \left[\beta - \frac{\gamma}{2} Q_t - \frac{\gamma}{2} Z_t \right].$$

Substituting into (20) and (21) yields $Z_t = \frac{2}{\gamma}\beta - \frac{1-2\pi_t}{1-\pi_t} Q_t + \frac{4}{\gamma}\frac{\pi_t}{1-\pi_t} h - \frac{2}{[1-\pi_t]\gamma}\frac{\alpha-\sigma_{t-1}}{\rho}$ and $Z_t = \frac{1}{2\pi_t m - \gamma[1-\pi_t]} \left\{ \frac{2}{\rho}[\alpha - \sigma_{t-1} - 1] - [4\pi_t m + 2\pi_t\gamma - \gamma] Q_t - 4\frac{\pi_t}{\gamma}[2m+\gamma]h + \frac{2\pi_t[2m+\gamma]-2\gamma}{\gamma}\beta \right\}$, and therefore

$$Q_t = \frac{2\pi_t m\,[\alpha - \sigma_{t-1}] - [1-\pi_t]\gamma}{\rho\gamma\pi_t m} - \frac{4}{\gamma} h, \tag{A.12}$$

$$Z_t = \frac{2}{\gamma}\beta - \frac{4}{\gamma}\frac{\alpha - \sigma_{t-1}}{\rho} + \frac{1-2\pi_t}{\rho\pi_t m} + \frac{4}{\gamma} h. \tag{A.13}$$

Combination (III) implies $\theta_t^{Ob} > \theta_t^{YZ}$, because the black capacity constraint should not bind if party O wins but should be binding if party Y wins. Substituting (34), (35), (A.12) and (A.13) yields $-1 > 0$, which never holds. Consequently, combination (III) is ruled out. □

A.D. Case (II) vs. Case (IV)

Suppose that the capacities Z_t^{II} and Q_t^{II} are given by (36) and (37), and that party Y holds office. To determine the welfare of the young generation at time t if party Y implements the case (II) tax rate θ_t^{Yb}, we need $W_{t+1}^{oO,II}$ and $W_{t+1}^{oY,II}$, which can be written as[23]

$$
\begin{aligned}
W_{t+1}^{oO,II} = \beta & \frac{Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})}{2} - \frac{\gamma}{2}\frac{[Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})]^2}{4} \\
& - p_{t+1}^{O}(\sigma_t,\pi_{t+1})\frac{[Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})]}{2} + p_{t+1}^{O}(\sigma_t,\pi_{t+1})Z_{t+1}(\sigma_t,\pi_{t+1}) \\
& - \frac{m}{2}\left[Z_{t+1}(\sigma_t,\pi_{t+1})\right]^2 + p_{t+1}^{O}(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1}) \\
& - h\left[Z_{t+1}(\sigma_t,\pi_{t+1}) + \delta b_t^{s,II}(\sigma_{t-1},\pi_t) + \delta^2 E_{t-1}\right], \\
W_{t+1}^{oY,II} = \beta & \frac{b_{t+1}^{s}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})}{2} - \frac{\gamma}{2}\frac{\left[b_{t+1}^{s}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})\right]^2}{4} \\
& - p_{t+1}^{Y}(\sigma_t,\pi_{t+1})\frac{b_{t+1}^{s}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})}{2} + p_{t+1}^{Y}(\sigma_t,\pi_{t+1})b_{t+1}^{s}(\sigma_t,\pi_{t+1}) \\
& - \frac{m}{2}\left[b_{t+1}^{s}(\sigma_t,\pi_{t+1})\right]^2 - \theta_{t+1}^{Y}(\sigma_t,\pi_{t+1})b_{t+1}^{s}(\sigma_t,\pi_{t+1}) + p_{t+1}^{Y}(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1}) \\
& + \frac{\theta_{t+1}^{Y}(\sigma_t,\pi_{t+1})b_{t+1}^{s}(\sigma_t,\pi_{t+1}) - \sigma_{t+1}Q_{t+2}(\sigma_{t+1},\pi_{t+2})}{2} \\
& - h\left[b_{t+1}^{s}(\sigma_t,\pi_{t+1}) + \delta b_t^{s,II}(\sigma_{t-1},\pi_t) + \delta^2 E_{t-1}\right],
\end{aligned}
$$

where $b_t^{s,II}$ is given by (40). Consequently, welfare at time t under case (II) policy reads

$$
\begin{aligned}
W_t^{yY,II} = \beta & \frac{b_t^{s,II}(\sigma_{t-1},\pi_t) + Q_t^{II}(\sigma_{t-1},\pi_t)}{2} - \frac{\gamma}{2}\frac{\left[b_t^{s,II}(\sigma_{t-1},\pi_t) + Q_t^{II}(\sigma_{t-1},\pi_t)\right]^2}{4} \\
& - p_t^{II}(\sigma_{t-1},\pi_t)\frac{\left[b_t^{s,II}(\sigma_{t-1},\pi_t) + Q_t^{II}(\sigma_{t-1},\pi_t)\right]}{2} + L - [\alpha - \sigma_t]Q_{t+1}(\sigma_t,\pi_{t+1}) \\
& - Z_{t+1}(\sigma_t,\pi_{t+1}) + \frac{\theta_t^{Yb}(\sigma_{t-1},\pi_t)b_t^{s,II}(\sigma_{t-1},\pi_t) - \sigma_t Q_{t+1}(\sigma_t,\pi_{t+1})}{2} \\
& - h\left[b_t^{s,II}(\sigma_{t-1},\pi_t) + \delta E_{t-1}\right] + \rho\left\{\pi_{t+1}W_{t+1}^{oO,II} + [1-\pi_{t+1}]W_{t+1}^{oY,II}\right\},
\end{aligned}
$$

where p_t^{II} is given by (41).

If party Y implements the tax rate θ_t^{YZ}, i.e. the case (IV) type policy, the welfare functions for period $t+1$ read

$$
\begin{aligned}
W_{t+1}^{oO,IV,II} = \beta & \frac{Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})}{2} - \frac{\gamma}{2}\frac{[Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})]^2}{4} \\
& - p_{t+1}^{O}(\sigma_t,\pi_{t+1})\frac{[Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})]}{2} + p_{t+1}^{O}(\sigma_t,\pi_{t+1})Z_{t+1}(\sigma_t,\pi_{t+1}) \\
& - \frac{m}{2}\left[Z_{t+1}(\sigma_t,\pi_{t+1})\right]^2 + p_{t+1}^{O}(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1}) \\
& - h\left[Z_{t+1}(\sigma_t,\pi_{t+1}) + \delta Z_t^{II}(\sigma_{t-1},\pi_t) + \delta^2 E_{t-1}\right],
\end{aligned}
$$

[23]To ease notation, we take account of (48).

$$
\begin{aligned}
W_{t+1}^{oY,IV,II} &= \beta \frac{b_{t+1}^s(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})}{2} - \frac{\gamma}{2}\frac{\left[b_{t+1}^s(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})\right]^2}{4} \\
&\quad - p_{t+1}^Y(\sigma_t,\pi_{t+1})\frac{b_{t+1}^s(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})}{2} + p_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1}) \\
&\quad - \frac{m}{2}\left[b_{t+1}^s(\sigma_t,\pi_{t+1})\right]^2 - \theta_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1}) + p_{t+1}^Y(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1}) \\
&\quad + \frac{\theta_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1}) - \sigma_{t+1}Q_{t+2}(\sigma_{t+1},\pi_{t+2})}{2} \\
&\quad - h\left[b_{t+1}^s(\sigma_t,\pi_{t+1}) + \delta Z_t^{II}(\sigma_{t-1},\pi_t) + \delta^2 E_{t-1}\right].
\end{aligned}
$$

Thus, welfare of the young generation in period t is given by

$$
\begin{aligned}
W_t^{yY,IV,II} &= \beta \frac{Z_t^{II}(\sigma_{t-1},\pi_t) + Q_t^{II}(\sigma_{t-1},\pi_t)}{2} - \frac{\gamma}{2}\frac{\left[Z_t^{II}(\sigma_{t-1},\pi_t) + Q_t^{II}(\sigma_{t-1},\pi_t)\right]^2}{4} \\
&\quad - p_t^{IV,II}(\sigma_{t-1},\pi_t)\frac{\left[Z_t^{II}(\sigma_{t-1},\pi_t) + Q_t^{II}(\sigma_{t-1},\pi_t)\right]}{2} + L - [\alpha - \sigma_t]Q_{t+1}(\sigma_t,\pi_{t+1}) \\
&\quad - Z_{t+1}(\sigma_t,\pi_{t+1}) + \frac{\theta_t^{YZ,II}(\sigma_{t-1},\pi_t)Z_t^{II}(\sigma_{t-1},\pi_t) - \sigma_t Q_{t+1}(\sigma_t,\pi_{t+1})}{2} \\
&\quad - h\left[Z_t^{II}(\sigma_{t-1},\pi_t) + \delta E_{t-1}\right] + \rho\left\{\pi_{t+1}W_{t+1}^{oO,IV,II} + [1-\pi_{t+1}]W_{t+1}^{oY,IV,II}\right\},
\end{aligned}
$$

where the tax rate $\theta_t^{YZ,II}(\sigma_{t-1},\pi_t)$ and the price $p_t^{IV,II}(\sigma_{t-1},\pi_t)$ read

$$
\begin{aligned}
\theta_t^{YZ,II}(\sigma_{t-1},\pi_t) &= \beta - \frac{\gamma}{2}Q_t^{II}(\sigma_{t-1},\pi_t) - \frac{2m+\gamma}{2}Z_t^{II}(\sigma_{t-1},\pi_t), \\
p_t^{IV,II}(\sigma_{t-1},\pi_t) &= \beta - \frac{\gamma}{2}\left[Z_t^{II}(\sigma_{t-1},\pi_t) + Q_t^{II}(\sigma_{t-1},\pi_t)\right].
\end{aligned}
$$

The welfare difference is given by

$$
\begin{aligned}
\Delta^{II} &= W_t^{yY,II} - W_t^{yY,IV,II} \\
&= \frac{\{[4m+\gamma][\pi[\alpha-\sigma_{t-1}]-1] - 2\rho m\pi_t[\beta - 2[1+\rho\delta]h]\}^2}{2[4m+\gamma][2m+\gamma\pi_t\{1-\pi_t\}]^2\rho^2}. \qquad \text{(A.14)}
\end{aligned}
$$

Suppose now that the capacities Z_t^{IV} and Q_t^{IV} are given by (43) and (44). If the Y-government at time t implements the tax rate θ_t^{YZ}, the welfare functions for period $t+1$ read

$$
\begin{aligned}
W_{t+1}^{oO,IV} &= \beta \frac{Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})}{2} - \frac{\gamma}{2}\frac{\left[Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})\right]^2}{4} \\
&\quad - p_{t+1}^O(\sigma_t,\pi_{t+1})\frac{\left[Z_{t+1}(\sigma_t,\pi_{t+1}) + Q_{t+1}(\sigma_t,\pi_{t+1})\right]}{2} + p_{t+1}^O(\sigma_t,\pi_{t+1})Z_{t+1}(\sigma_t,\pi_{t+1}) \\
&\quad - \frac{m}{2}\left[Z_{t+1}(\sigma_t,\pi_{t+1})\right]^2 + p_{t+1}^O(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1}) \\
&\quad - h\left[Z_{t+1}(\sigma_t,\pi_{t+1}) + \delta Z_t^{IV}(\sigma_{t-1},\pi_t) + \delta^2 E_{t-1}\right],
\end{aligned}
$$

$$
\begin{aligned}
W_{t+1}^{oY,IV} &= \beta\frac{b_{t+1}^s(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})}{2}-\frac{\gamma}{2}\frac{\left[b_{t+1}^s(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})\right]^2}{4}\\
&-p_{t+1}^Y(\sigma_t,\pi_{t+1})\frac{b_{t+1}^s(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})}{2}+p_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1})\\
&-\frac{m}{2}\left[b_{t+1}^s(\sigma_t,\pi_{t+1})\right]^2-\theta_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1})+p_{t+1}^Y(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1})\\
&+\frac{\theta_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1})-\sigma_{t+1}Q_{t+2}(\sigma_{t+1},\pi_{t+2})}{2}\\
&-h\left[b_{t+1}^s(\sigma_t,\pi_{t+1})+\delta Z_t^{IV}(\sigma_{t-1},\pi_t)+\delta^2E_{t-1}\right].
\end{aligned}
$$

Consequently, welfare of the young generation at time t is given by

$$
\begin{aligned}
W_t^{yY,IV} &= \beta\frac{Z_t^{IV}(\sigma_{t-1},\pi_t)+Q_t^{IV}(\sigma_{t-1},\pi_t)}{2}-\frac{\gamma}{2}\frac{\left[Z_t^{IV}(\sigma_{t-1},\pi_t)+Q_t^{IV}(\sigma_{t-1},\pi_t)\right]^2}{4}\\
&-p_t^{IV}(\sigma_{t-1},\pi_t)\frac{\left[Z_t^{IV}(\sigma_{t-1},\pi_t)+Q_t^{IV}(\sigma_{t-1},\pi_t)\right]}{2}+L-[\alpha-\sigma_t]Q_{t+1}(\sigma_t,\pi_{t+1})\\
&-Z_{t+1}(\sigma_t,\pi_{t+1})+\frac{\theta_t^{Yb}(\sigma_{t-1},\pi_t)Z_t^{IV}(\sigma_{t-1},\pi_t)-\sigma_tQ_{t+1}(\sigma_t,\pi_{t+1})}{2}\\
&-h\left[Z_t^{IV}(\sigma_{t-1},\pi_t)+\delta E_{t-1}\right]+\rho\left\{\pi_{t+1}W_{t+1}^{oO,IV}+[1-\pi_{t+1}]W_{t+1}^{oY,IV}\right\},
\end{aligned}
$$

where p_t^{IV} is determined by (45).

If the Y-government implements the case (II) policy, i.e. the tax rate θ_t^{Yb}, the welfare functions for period $t+1$ read

$$
\begin{aligned}
W_{t+1}^{oO,II,IV} &= \beta\frac{Z_{t+1}(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})}{2}-\frac{\gamma}{2}\frac{\left[Z_{t+1}(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})\right]^2}{4}\\
&-p_{t+1}^O(\sigma_t,\pi_{t+1})\frac{\left[Z_{t+1}(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})\right]}{2}+p_{t+1}^O(\sigma_t,\pi_{t+1})Z_{t+1}(\sigma_t,\pi_{t+1})\\
&-\frac{m}{2}\left[Z_{t+1}(\sigma_t,\pi_{t+1})\right]^2+p_{t+1}^O(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1})\\
&-h\left[Z_{t+1}(\sigma_t,\pi_{t+1})+\delta b_t^{s,II,IV}(\sigma_{t-1},\pi_t)+\delta^2E_{t-1}\right],\\
W_{t+1}^{oY,II,IV} &= \beta\frac{b_{t+1}^s(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})}{2}-\frac{\gamma}{2}\frac{\left[b_{t+1}^s(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})\right]^2}{4}\\
&-p_{t+1}^Y(\sigma_t,\pi_{t+1})\frac{b_{t+1}^s(\sigma_t,\pi_{t+1})+Q_{t+1}(\sigma_t,\pi_{t+1})}{2}+p_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1})\\
&-\frac{m}{2}\left[b_{t+1}^s(\sigma_t,\pi_{t+1})\right]^2-\theta_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1})+p_{t+1}^Y(\sigma_t,\pi_{t+1})Q_{t+1}(\sigma_t,\pi_{t+1})\\
&+\frac{\theta_{t+1}^Y(\sigma_t,\pi_{t+1})b_{t+1}^s(\sigma_t,\pi_{t+1})-\sigma_{t+1}Q_{t+2}(\sigma_{t+1},\pi_{t+2})}{2}\\
&-h\left[b_{t+1}^s(\sigma_t,\pi_{t+1})+\delta b_t^{s,II,IV}(\sigma_{t-1},\pi_t)+\delta^2E_{t-1}\right].
\end{aligned}
$$

To determine

$$
b_t^{s,II,IV}=\frac{2\beta-2\theta_t^{Yb,IV}(\sigma_{t-1},\pi_t)-\gamma Q_t^{IV}(\sigma_{t-1},\pi_t)}{2m\gamma},
$$

we have to take account of

$$\theta_t^{Yb,IV} = -\frac{\gamma}{2}Q_t^{IV}(\sigma_{t-1},\pi_t) + \frac{4m+2\gamma}{4m+\gamma}[1+\rho\delta]h + \frac{2m}{4m+\gamma}\beta.$$

The welfare of the young generation of period t reads

$$\begin{aligned} W_t^{yY,II,IV} &= \beta\frac{b_t^{s,II,IV}(\sigma_{t-1},\pi_t) + Q_t^{IV}(\sigma_{t-1},\pi_t)}{2} - \frac{\gamma}{2}\frac{\left[b_t^{s,II,IV}(\sigma_{t-1},\pi_t) + Q_t^{IV}(\sigma_{t-1},\pi_t)\right]^2}{4} \\ &\quad - p_t^{II,IV}(\sigma_{t-1},\pi_t)\frac{\left[b_t^{s,II,IV}(\sigma_{t-1},\pi_t) + Q_t^{IV}(\sigma_{t-1},\pi_t)\right]}{2} + L - [\alpha-\sigma_t]Q_{t+1}(\sigma_t,\pi_{t+1}) \\ &\quad - Z_{t+1}(\sigma_t,\pi_{t+1}) + \frac{\theta_t^{Yb,IV}(\sigma_{t-1},\pi_t)b_t^{s,II,IV}(\sigma_{t-1},\pi_t) - \sigma_t Q_{t+1}(\sigma_t,\pi_{t+1})}{2} \\ &\quad - h\left[b_t^{s,II,IV}(\sigma_{t-1},\pi_t) + \delta E_{t-1}\right] + \rho\left\{\pi_{t+1}W_{t+1}^{oO,II,IV} + [1-\pi_{t+1}]W_{t+1}^{oY,II,IV}\right\}, \end{aligned}$$

with

$$p_t^{II,IV} = \frac{2m\beta + \gamma\theta_t^{Yb,IV}(\sigma_{t-1},\pi_t)}{2m+\gamma} - \frac{m\gamma Q_t^{IV}(\sigma_{t-1},\pi_t)}{2m+\gamma}.$$

The welfare difference reads

$$\begin{aligned} \Delta^{IV} &= W_t^{yY,II,IV} - W_t^{yY,IV} \\ &= \frac{\{[4m+\gamma][\pi[\alpha-\sigma_{t-1}]-1] - 2\rho m\pi_t[\beta - 2[1+\rho\delta]h]\}^2}{8m^2[4m+\gamma]\pi_t^2\rho^2}. \end{aligned} \tag{A.15}$$

Both (A.14) and (A.15) describe a parabola with a zero at $\sigma_{t-1} = \tilde{\sigma}_{t-1}$ and positive values for all $\sigma_{t-1} \neq \tilde{\sigma}_{t-1}$. □

A.E. Proof of Proposition 9

The subsidy rate of case (II) can be only set if $\sigma_{t-1}^{II} \in [0, \tilde{\sigma}_{t_1}]$. The upper limit implies that $\sigma_{t-1}^{\Delta II} = \tilde{\sigma}_{t_1} - \sigma_{t-1}^{II} \geq 0$ has to hold. The interval $[0, \tilde{\sigma}_{t_1}]$ only exists if $\tilde{\sigma}_{t-1} \geq 0$. Because $\frac{d\sigma_{t-1}^{II}}{d\alpha} < 0$, $\frac{d\sigma_{t-1}^{\Delta II}}{d\alpha} > 0$, $\frac{d\tilde{\sigma}_{t-1}}{d\alpha} > 0$, and $\frac{d^2\sigma_{t-1}^{II}}{d\alpha^2} = \frac{d^2\sigma_{t-1}^{\Delta II}}{d\alpha^2} = \frac{d^2\tilde{\sigma}_{t-1}}{d\alpha^2} = 0$, σ_{t-1}^{II} linearly decreases in α, while both $\sigma_{t-1}^{\Delta II}$ and $\tilde{\sigma}_{t-1}$ linearly increase in α. The zeros are given by α^{II}, $\alpha^{\Delta II}$ and $\alpha^{\min II}$, which proves Proposition 9(i).

The subsidy of case (IV) can be only set if $\sigma_{t-1}^{IV} \in [\tilde{\sigma}_{t_1}, \alpha-1]$ and $\sigma_{t-1}^{IV} \geq 0$. The former lower limit implies that $\sigma_{t-1}^{\Delta IV} = \tilde{\sigma}_{t_1} - \sigma_{t-1}^{IV} \leq 0$ has to hold. The latter lower limit implies that $\Delta^{\min} = \alpha - 1 - \sigma_{t-1}^{\Delta IV} \geq 0$ has to hold. Because $\frac{d\sigma_{t-1}^{IV}}{d\alpha} < 0$, $\frac{d\sigma_{t-1}^{\Delta IV}}{d\alpha} > 0$, $\frac{d\Delta^{\min}}{d\alpha} > 0$, and $\frac{d^2\sigma_{t-1}^{IV}}{d\alpha^2} = \frac{d^2\sigma_{t-1}^{\Delta IV}}{d\alpha^2} = \frac{d^2\Delta^{\min}}{d\alpha^2} = 0$, σ_{t-1}^{IV} linearly decreases in α, while both $\sigma_{t-1}^{\Delta IV}$ and $\Delta^{\min}$ linearly increase in α. The zeros are given by α^{IV}, $\alpha^{\Delta IV}$ and $\alpha^{\min IV}$, which proves Proposition 9(ii).

Suppose that both σ_{t-1}^{II} and σ_{t-1}^{IV} are feasible for some α. Then, a Y-government will set the subsidy rate σ_{t-1}^{II} at time $t-1$ if $\Delta W_{t-1} = W_{t-1}^{yY}(\sigma_{t-1}^{II}) - W_{t-1}^{yY}(\sigma_{t-1}^{IV})$. By differentiating ΔW_{t-1}, we find

$$\frac{d^2 \Delta W_{t-1}}{d\alpha^2} = \frac{-[1-\pi_t]}{8\rho m^2[4m+\gamma]^2\pi_t\Big\{4m^2+4m\gamma[1-\pi_t]^2\pi_t+\gamma^2\pi_t^2[1-\pi_t]\Big\}}$$
$$\Bigg\{2\gamma^5\pi_t^3 + 8m\gamma^4\pi_t^2[1+2\pi_t] + 32m^3\gamma^2\pi_t\Big[3+[15-7\pi_t]\pi_t\Big]$$
$$+ 128m^4\gamma\pi_t\Big[3+[7-5\pi_t]\pi_t\Big] + 512m^5\pi_t\Big[1+[1-\pi_t]\pi_t\Big]$$
$$+ 8m^2\gamma^3\pi_t\Big[1+\pi_t[13+\pi_t]\Big]\Bigg\} < 0.$$

Consequently, the extremum of ΔW_{t-1} at

$$\alpha^{\max} = \frac{1}{\pi_t\Big\{4m^2[4m+\gamma]^2+4m[m+\gamma][4m+\gamma]^2\pi_t-[2m+\gamma]^2[16m^2-\gamma^2]\pi_t^2\Big\}}$$
$$\Bigg\{\gamma^4\pi_t^3[1+2h\rho] + 2m\gamma^3\pi_t^2\Big[3+\pi_t+2h[2+\pi_t]\rho\Big]$$
$$+ 16m^4\Big[2+\pi_t\Big[4-4\pi_t+[2h+\beta]\rho+2\pi_t\rho[\beta[1-\pi_t]+2h\pi_t]-2h\delta[1+2[1-\pi_t]\pi_t]\rho^2\Big]\Big]$$
$$+ 4m^2\gamma^2\pi_t\Big[3+2h\rho+7\pi_t[1+2h\rho]-\pi_t^2\Big[4-\beta\rho+2h\rho[4+\delta\rho]\Big]\Big]$$
$$+ 8m^3\gamma\Big[1+\pi_t\Big[8+6h\rho-\pi_t[4\pi_t-2h[5-\pi_t]\rho+\beta[2-\pi_t]\rho-2h\delta[2-\pi_t]\rho^2]\Big]\Big]\Bigg\}$$

is a maximum. The zeros are given by $\alpha = \pm\tilde{\alpha}$, so that the government chooses σ_{t-1}^{II} if $\alpha < \tilde{\alpha}$. □

The relations of $\alpha^{\min II}$, $\alpha^{\min IV}$, α^{II}, $\alpha^{\Delta II}$, α^{IV} and $\alpha^{\Delta IV}$ used for Fig. 3 are given by

$$\alpha^{IV} - \alpha^{\min IV} = \frac{4\rho m h}{2m+\gamma} > 0,$$
$$\alpha^{\Delta IV} - \alpha^{IV} = \frac{2m}{[2m+\gamma]\pi_t} + \frac{4\rho m^2\{\beta-2[1+\rho\delta]h\}}{[2m+\gamma][4m+\gamma]} - \frac{2m[1+2\rho h]}{2m+\gamma},$$
$$\alpha^{\min II} - \alpha^{\Delta IV} = \frac{\gamma[1-\pi_t-2\rho\pi_t h]}{[2m+\gamma]\pi_t} + \frac{2\rho m\gamma\{\beta-2[1+\rho\delta]h\}}{[2m+\gamma][4m+\gamma]},$$
$$\alpha^{\Delta II} - \alpha^{\min II} = \frac{2\gamma\rho\pi_t\{h\pi_t[4m+\gamma]-m[\beta-2[1+\rho\delta]h]\}}{[4m+\gamma][2m+\gamma\pi_t]},$$
$$\alpha^{II} - \alpha^{\Delta II} = \rho\frac{\{4m^2+4m\pi_t\gamma[1-\pi_t]^2+\gamma^2\pi_t^2[1-\pi_t]\}\{h\pi_t[4m+\gamma]-m[\beta-2[1+\rho\delta]h]\}}{m[4m+\gamma]\pi_t[3-2\pi_t][2m+\gamma\pi_t]}.$$

If both π_t and $\beta - 2[1+\rho\delta]h$ are sufficiently small, all stated differences are positive.

A.F. Changing the election probability by setting subsidies

In case (II) we can derive a closed form expression for $\frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}}$ using (56):

$$
\begin{aligned}
&\text{(A.16)}\qquad \frac{\mathrm{d}\pi_t}{\mathrm{d}\sigma_{t-1}} = \Bigg\{ \frac{1}{(4m+\gamma)\nu(2m-\gamma(\pi_t-1)\pi_t)} \\
&\frac{1}{(4(\pi_t(2\alpha(\pi_t-2)-\beta\rho(\pi_t-2)+2h\rho(\pi_t+\delta(\pi_t-1)\rho)-2\pi_t\sigma_{t-1}+4\sigma_{t-1}-2)+2)m^2+2\gamma\left(\pi_t\left(-2h\rho(\delta\rho+2)\pi_t^2+(2h\rho+\beta\rho+\sigma_{t-1}+2)\pi_t-\alpha(\pi_t+2)+h\rho(\delta\rho+2)+2\sigma_{t-1}-1\right)+1\right)m+\gamma^2\pi_t^2(-\alpha-h(\pi_t-1)\rho(\delta\rho+2)+\sigma_{t-1}+1))} \\
&\Bigg[128\rho^2m^5+16\Bigg(4\nu(\pi_t-1)\alpha^2-4\nu(\beta(\pi_t-1)\rho+h(\delta\rho-2(\delta\rho\pi_t+\pi_t))\rho+2(\pi_t-1)\sigma_{t-1}+1)\alpha+4\nu(\pi_t-1)\sigma_{t-1}^2 \\
&+\rho\left(4\nu\rho(\delta\rho+1)(\delta\rho\pi_t+\pi_t+1)h^2-2\nu(2\beta\pi_t\rho+\delta(\beta(2\pi_t-1)\rho+2)\rho+2)h+2\beta\nu+4\gamma\rho+(\pi_t-1)\left(\beta^2\nu-12\gamma\pi_t\right)\rho\right)+4\nu(\beta(\pi_t-1)\rho+h(\delta\rho-2(\delta\rho\pi_t+\pi_t))\rho+1)\sigma_{t-1}\Bigg)m^4 \\
&+8\gamma(\gamma\left(12\left(\pi_t^4-2\pi_t^3+\pi_t\right)+1\right)\rho^2 \\
&+\nu((\beta\rho-2h(\delta\rho+1)\rho+2\sigma_{t-1})^2\pi_t^3-3(-\beta\rho+2h(\delta\rho+1)\rho-2\sigma_{t-1})(-\beta\rho+2h(\delta\rho+1)\rho-2\sigma_{t-1}+2)\pi_t^2+2\left(2h^2(\delta\rho+1)(\delta\rho+2)\rho^2+\beta(\sigma_{t-1}-7)\rho-h(-10\delta\rho+\beta(\delta\rho+2)\rho+4\delta\sigma_{t-1}\rho+6\sigma_{t-1}-6)\rho+2(\sigma_{t-1}-7)\sigma_{t-1}+4\right)\pi_t \\
&-4\sigma_{t-1}^2+4\alpha^2\left(\pi_t^3-3\pi_t^2+\pi_t-1\right)+5\beta\rho+h\rho(-6\delta\rho-\beta(\delta\rho+2)\rho+2h(\delta\rho+1)(\delta\rho+2)\rho-2)-2(2h+\beta)\rho\sigma_{t-1}+12\sigma_{t-1} \\
&+2\alpha\left(2h\rho+\beta\rho+4\sigma_{t-1}+\pi_t\left((-2\beta\rho+4h(\delta\rho+1)\rho-4\sigma_{t-1})\pi_t^2-6(-\beta\rho+2h(\delta\rho+1)\rho-2\sigma_{t-1}+1)\pi_t-\beta\rho+2h\rho(2\delta\rho+3)-4\sigma_{t-1}+14\right)-6\right)-8))m^3 \\
&-4\gamma^2(\gamma(\pi_t-1)\pi_t(2(\pi_t-2)\pi_t-1)\left(2\pi_t^2-3\right)\rho^2 \\
&+\nu(2h\rho(\delta\rho+2)(-\beta\rho+2h(\delta\rho+1)\rho-2\sigma_{t-1})\pi_t^4+\left(8\sigma_{t-1}+\rho\left(-4\rho(\delta\rho+1)h^2-2\delta\rho(\beta\rho+8)h+4(\sigma_{t-1}-6)h+\beta(\beta\rho+2\sigma_{t-1}+4)\right)\right)\pi_t^3 \\
&-3(-4(\sigma_{t-1}-1)\sigma_{t-1}+\beta(\rho-2\rho\sigma_{t-1})+2h\rho(2\sigma_{t-1}+\delta\rho(2\sigma_{t-1}-3)-5)-4)\pi_t^2-\left(\sigma_{t-1}^2-4h\rho(\delta\rho+2)\sigma_{t-1}-28\sigma_{t-1}-7\beta\rho+h\rho(10\delta\rho-\beta(\delta\rho+2)\rho+2h(\delta\rho+1)(\delta\rho+2)\rho+6)+20\right)\pi_t \\
&+\sigma_{t-1}^2+\alpha^2(\pi_t(12\pi_t-1)+1)-2(2h+\beta)\rho+h\rho(\delta\rho+2)\sigma_{t-1}-9\sigma_{t-1}+\alpha\left(4h\rho(\delta\rho+2)\pi_t^4-2(2h\rho+\beta\rho+4)\pi_t^3+6(-\beta\rho+2h(\delta\rho+1)\rho-4\sigma_{t-1}+2)\pi_t^2+2(-2h\rho(\delta\rho+2)+\sigma_{t-1}-14)\pi_t-h\rho(\delta\rho+2)-2\sigma_{t-1}+9\right)+12))m^2 \\
&-2\gamma^3(\gamma(\pi_t-1)^2\pi_t^2(2\pi_t-3)(2\pi_t+1)\rho^2+\nu(h\rho(\delta\rho+2)(-\beta\rho+2h(\delta\rho+1)\rho-4\sigma_{t-1})\pi_t^4+\left(-2h^2(\delta\rho+1)(\delta\rho+2)\rho^2+2\beta(\sigma_{t-1}+1)\rho+h(\beta\rho(\delta\rho+2)+4(-3\delta\rho+\sigma_{t-1}-5))\rho+\sigma_{t-1}(3\sigma_{t-1}+8)\right)\pi_t^3 \\
&+3\alpha^2(\pi_t+1)\pi_t^2+3(4h\rho(\delta\rho+2)+(\sigma_{t-1}-1)\sigma_{t-1}+4)\pi_t^2+(h\rho(\delta\rho+2)+7)(\sigma_{t-1}-2)\pi_t-h\rho(\delta\rho+2)-2\sigma_{t-1}+\alpha\left(\pi_t\left(4h\rho(\delta\rho+2)\pi_t^3-2(2h\rho+\beta\rho+3\sigma_{t-1}+4)\pi_t^2+(3-6\sigma_{t-1})\pi_t-h\rho(\delta\rho+2)-7\right)+2\right)+6))m \\
&-\gamma^4\left(\gamma(\pi_t-1)^3\rho^2\pi_t^3+\nu\left(h\rho(\delta\rho+2)(\alpha-\sigma_{t-1})\pi_t^3+\left(\alpha^2-(h\rho(\delta\rho+2)+2(\sigma_{t-1}+1))\alpha+h\rho(\delta\rho+2)(\sigma_{t-1}-2)+\sigma_{t-1}(\sigma_{t-1}+2)\right)\pi_t^2+3(h\rho(\delta\rho+2)+1)\pi_t-h\rho(\delta\rho+2)-3\right)\pi_t+\nu\right)\Bigg]\Bigg\}^{-1}.
\end{aligned}
$$

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