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Strategic choice of stock pollution: Why conservatives (appear to) turn green

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Strategic Choice of Stock Pollution: Why Conservatives (Appear To) Turn Green*

Achim Voß[†]

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Abstract

The public management of stock pollutants is an intertemporal problem; today's optimal choice takes the behavior of future governments into account. If a government expects a successor with different environmental preferences – for instance, if “Conservatives” expect “green” successors – it must choose strategically. I model this interaction in a two-period game in which the government of each period chooses consumption as a flow variable that adds to a stock of pollution. In this setting, I analyze how the prospect of losing political power changes the incumbent's policy choice. It is shown that *both* the prospect of a more “conservative” or of a “greener” successor reduce present consumption. This implies that losing power in the future makes a conservative government choose a compromise policy today – which may explain why in some countries, conservative governments seem to adopt green policies. By contrast, the expected loss of power makes a green government choose a policy that appears as a radicalization of their position.

Keywords: Stock Pollution; Political Economy of Environmental Policy; Time Inconsistency; Strategic choice of stock variables; Sequential Game; Partisan Politicians; Ideological Preferences; Green Parties

JEL Codes: Q58; D72; C72

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1 Introduction

How much should society consume today if consumption activities add to a stock of pollution? The usual intertemporally optimal choice balances today's marginal consumption utility and today's and tomorrow's marginal damage cost of the stock pollutant. However, there is no omniscient and benevolent "social planner" in reality, and politicians often disagree about the social cost of pollution. In balancing environmental quality against consumption, *green* parties are more concerned about the former and *conservative* parties emphasize the latter.¹

In a democracy, a governing green party has to consider that its successor might not care as much about environmental policy. Similarly, if a conservative party is in power today, it has to take into account that it might be replaced by Greens who are sensitive to the pollution stock they inherit and drastically restrict consumption. In both cases, this expectation changes the incumbent's optimal policy. Even though today's governing party is unable to determine future consumption and pollution, because it will not be in power indefinitely, it can adjust present consumption, as this may influence future choices. Accordingly, environmental policy assumes a strategic role.

In this article, I analyze the resulting strategic interaction between conservative and green governments as a sequential game in two periods. I assume that the political parties, which succeed each other in government, are ideologically motivated; that is, they do not care about being in office *per se*, but only about the policy implemented by the government. In order to focus on the strategic interaction, both the political preferences of the parties and the probability with which they are elected are exogenous.²

To grasp the model's intuition, firstly, as a benchmark, suppose that one party is in power forever. It regulates how much the economy consumes and thereby simultaneously chooses the growth of the stock of pollution. Because the Greens' aversion to pollution is stronger than that of the Conservatives, a green government would choose a path of lower consumption and pollution than a conservative one in the same situation.

I demonstrate that expecting a conservative successor will further constrain the green government's consumption; it partly makes good for additional future pollution

¹To avoid misunderstandings, it is necessary to point out three things. Firstly, in this article "consumption" refers to activities that have benefits but cause pollution – e.g., driving a car. I focus only on consumption and do not analyze investment. If it is production that pollutes, then certainly, "Conservatives" would often not only consume more, but also invest more than "Greens". Secondly, in this article the party labels have no further implications than describing the valuation of the social cost of pollution. In this sense, parties traditionally understood as "left-wing" (or Labor) parties can also be "conservative", depending on their environmental-policy position. Thirdly, the analysis in this article is independent of which valuation of social cost is "correct" and of whether a "correct" valuation exists at all.

²A working paper version containing simple microfoundations is available upon request from the author. To endogenize elections, the reason for an expected change of government may be a change of the median voter's identity, for example due to "random shocks to the costs of voting" or "changes in the eligibility of the voting population" as discussed by Tabellini and Alesina (1990).

by stricter consumption abstinence today. However, this is not a lever to force the succeeding government also to reduce consumption – quite the contrary in fact, it will choose more consumption if it inherits less pollution. But due to the trade-off between consumption and pollution, future additional consumption will be less than the present reduction, so that the total pollution stock will be smaller in the future.

What is more, a conservative incumbent expecting to be replaced by a green successor also reduces consumption away from its preferred present level to avoid extreme reductions in the future. Therefore, the expectation of being replaced seems to make both a green government's and a conservative government's policy greener in the present, so that the former appears to radicalize and the latter appears to choose a compromise position – even though none of the parties has changed its intrinsic preferences.

The remainder of the article is structured as follows. Section 2 provides a short discussion of related literature. In Section 3, I present the model and derive its solution. Section 4 analyzes the impact of binding agreements, and the effects of uncertainty, discounting, and natural removal of the pollution stock. Finally, Section 5 summarizes, discusses the findings and suggests directions for future research.

2 Relation to the Literature

The model in this article offers an explanation why less environmentalist parties should behave greener when they expect future green governments. It implies that the greening of conservative parties should be pushed by a perception that environmentalist governments in the future are more likely than they were in the past. One factor for this is the establishment of green parties in many countries in the past decades. What is more, the young tend to have a higher share of green voters (Cf. Dolezal, 2010), raising the probability for the future.

This paper is motivated by anecdotal evidence found in German media that the German conservatives have adopted positions originally to be found within the Green Party (for example, cf. Görtz, 2013). Such policy convergence can be found in other countries as well. Carter (2013) evaluates expert opinions about the positions of political parties in a cross-section of (mainly European) countries. He finds that major Social Democratic and Conservative parties³ are more likely to adopt green positions if there is a successful green party in their country (though the effect seems to be small). This fits the conservatives' compromise position predicted by my model. Obviously, this is hard to disentangle from a shift in the Median voter's preference. However, such a shift would require an explanation why there is still considerable difference in party positions. Moreover, a pure Median voter model relies on some kind of pre-electoral

³As pointed out in fn. 1, both *can* be “conservative” in the context of this paper.

commitment of political parties, which the exogenous-probabilities model of policy-motivated politicians in this paper does not.⁴

Do incumbents really behave differently when they expect not to be reelected? Fredriksson et al. (2011) tackle this question by testing whether being a “lame duck” (not being allowed to be reelected) has an impact on the growth rate of a set of environmental expenditures. They find that re-electable governors do not significantly differ between U.S. parties with respect to this rate. By contrast, in their lame-duck term, Democrats have a lower expenditure growth rate than Republicans. To test the current model, however, we would need to analyze the impact of the governor’s own preferences, the preferences of the expected successor, and the difference between the two on current policy.

Naturally, the model in general relates to the political-economy literature of environmental economics; see Oates and Portney (2003) for an excellent survey. A topic that has received growing interest in recent years concerns the time-consistency of environmental policy. Usually, the setting is that a government is unable to credibly commit, and while its intrinsic preferences do not change, it would later deviate from its announced policy, thus making announcements incredible (cf. Drazen, 2000, ch. 4); see, for example, Marsiliani and Renström (2000) and Abrego and Perroni (2002). Helm et al. (2003) discuss the time-consistency problem of climate policy and Brunner et al. (2012) survey the literature in this context.

In my model, political parties have time-consistent preferences, but as they succeed each other in government, the preferences of the government change (and, thus, are time-inconsistent). The results rest on the inability of political parties to commit (which is usual in democracies); in Section 4.1, I demonstrate how the political parties would improve their situation if the opposition could commit to post-election behavior. Other models in which the inability to commit leads to a strategic choice of stock variables have been discussed in the analysis of strategic debt accumulation of Persson and Svensson (1989), Tabellini and Alesina (1990), and Alesina and Tabellini (1990). In Persson and Svensson (1989), politicians disagree about the optimal *level* of public spending, and the latter two articles deal with disagreement on the *composition* of spending. Leaving behind a higher level of debt means that the successor has to raise more taxes for a given level of spending, which may, under certain circumstances, make accumulating high debt a rational strategy.

The strategic choice of stock variables is even more clearly applicable to pollution management than to debt choice.⁵ Therefore, the impact of today’s pollution on future

⁴However, the model is compatible with Median-voter models – see fn. 2.

⁵The debt literature relies on the assumption that today’s government debt has to be honored by tomorrow’s government. If creditors know that debt is chosen strategically and there is full information on this issue, equilibria without full repayment may seem possible. By contrast, stock pollution is indeed a physical stock.

behavior should naturally be taken into account. With regard to current policy, choosing the “right” amount of consumption and pollution is politically controversial, and this article contributes to understanding the political distortions characterizing the debates.

The model in this article follows Voß (2013), in which a similar setting is used to analyze the government’s choice of energy productivity investment. Given that the strategic choices on two important topics of environmental policy are covered, namely public energy productivity investment and stock pollution management, the two articles are complementary. Both models analyze a government’s strategic behavior when it takes into account that its successor has different preferences regarding the future consumption-pollution trade-off. In Voß (2013), the incumbent chooses energy productivity investment. An expected loss of power may lead to increased or reduced investment, depending on whether energy productivity and fuel are substitutes or complements. As in the current article, it does *not* matter for the strategic effect’s direction whether the future government is greener or more conservative. The current article demonstrates that similar strategic behavior occurs in the determination of stock pollution. However, due to the different structure of utility functions, no ambiguities arise with regard to the direction of impact.

A similar paper that analyzes climate-change policy with changing government preferences is Ulph and Ulph (2013). In their model, the government would like to set optimal carbon taxes, but it is unable to commit to the taxes that the future government will choose, and may therefore use R&D subsidies. The authors emphasize the effect of uncertainty about the future government’s preferences. In my model, I deliberately use a deterministic setting to demonstrate that the effects I discuss are *not* driven by uncertainty.

Finally, the model presented in this article is an extension of the stock-pollution management literature. Since the seminal contributions of Keeler et al. (1971), Plourde (1972), and Forster (1973), there is a rich literature analyzing dynamically optimal pollution. However, while these articles analyze the time paths of pollution chosen by a social planner in a fully dynamic setting, the current model concentrates on two periods, in order to focus on the strategic interaction between successive governments. In the literature, it is often assumed that aggregate welfare is, within each period, additively separable between a concave consumption benefit function and a convex stock pollution cost function (for example, cf. Forster, 1973, sec. 4, Tahvonen, 1997, or van der Ploeg and Withagen, 2012), and I assume this throughout.

3 The Model

3.1 Agents, Objective Functions and Temporal Structure

Consider an economy in two time-periods $t \in \{1, 2\}$. There are two political parties $i \in \{x, y\}$ that obtain utility from the economy's consumption of a good E and disutility from a stock S of pollution. Party i 's instantaneous utility in period t is

$$u_t^i(E_t, S_t) \equiv B(E_t) - \kappa_i Z(S_t), \quad (1)$$

where $B(E)$ represents consumption benefits, $Z(S)$ is the pollution damage function and $\kappa_i > 0$ is the damage valuation parameter of Party i , so that $\kappa_i Z(S_t)$ is Party i 's stock-pollution cost function. $B(E)$ is strictly concave and increasing at least for small E values; if there are direct costs of consumption, they are included in B , which then has a maximum. $Z(S)$ is strictly convex and increasing. Both functions are assumed to be sufficiently smooth, and the function inputs are non-negative.

The stock of pollution in period t is given by

$$S_t = E_t + (1 - \delta)S_{t-1}, \quad (2)$$

where δ is nature's regeneration rate. Thus, current pollution is composed of a consumption by-product and the proportion of past pollution that is not (yet) absorbed by the environment. Due to this stock-flow relationship, we can define utility in terms of the E values alone. The parties do not discount, so that intertemporal utility can be written as follows:

$$U^i(E_1, E_2) \equiv u_1^i(E_1) + u_2^i(E_1, E_2), \quad (3)$$

where S_0 is exogenous and thus dropped.

In each period, the party that is in power – the government – may choose E_t . The parties do not derive utility directly from being in power, but only from the E_1, E_2 choice; they are interested in the appropriate policy, not in “ego rents”. The only difference between the two parties is that one is more concerned about pollution than the other. In the following analysis, we call the party “green” that associates a higher cost with any level of pollution: If $\kappa_y > \kappa_x$, Party y is green (relative to Party x). The green party's counterpart will be called “conservative”. If one of the parties were in power in both periods, we would intuitively expect it to choose less consumption in both periods if it were green.

Now consider a change of government between periods. To standardize, we assume in the following that Party x is in power in the first period and anticipates to be replaced

by Party y . We still expect κ_x to have a negative effect on the consumption choice in the first period, E_1 . But what is the effect of κ_y ? Consumption adds to the pollution stock that the future government inherits, which in turn influences its policy. If the preferences of the two governments differ, a strategic component enters the consumption decision.

To analyze the resulting behavior, I discuss the first-period Party- x incumbent's optimal consumption in Section 3.3 and then compare the implications for both parties in Section 3.4. To find first-period consumption, it is necessary to first derive second-period behavior in order to solve backwards; I do so in the following Section 3.2.

3.2 Consumption in the Second Period

Party y is in power in $t = 2$. The first-period consumption and, thus, the inherited stock of pollution are predetermined, so that the government's objective function is given by

$$\max_{E_2} u_2^y(E_2) \equiv B(E_2) - \kappa_y Z(E_2 + (1 - \delta)S_1). \quad (4)$$

I focus on interior solutions. If such a solution exists, it is defined by the first-order condition

$$B'(E_2^y) - \kappa_y Z'(S_2^y) = 0, \quad (5)$$

where the y superscript denotes optimality from Party y 's point of view and $S_2^y \equiv E_2^y + (1 - \delta)S_1$.⁶ This choice balances the marginal benefits of consumption and the resulting marginal cost of pollution, as perceived by Party y . The first-order condition defines E_2^y as an implicit function of κ_y and of past consumption, due to the effect of the latter on inherited pollution. Differentiating (5), we obtain the following partial derivatives of $E_2^y(E_1, \kappa_y)$:

$$\frac{\partial E_2^y(E_1, \kappa_y)}{\partial \kappa_y} = -\frac{Z'(S_2^y)}{-B''(E_2^y) + \kappa_y Z''(S_2^y)} < 0, \quad (6)$$

$$\frac{\partial E_2^y(E_1, \kappa_y)}{\partial E_1} = -\frac{\kappa_y Z''(S_2^y)}{-B''(E_2^y) + \kappa_y Z''(S_2^y)} (1 - \delta) \in (0, -(1 - \delta)). \quad (7)$$

Expectedly, by (6), if the government cares more about pollution, it chooses less (polluting) consumption. The numerator shows the direct utility loss due to the higher valuation of marginal damage. This implies a reduction of consumption to cause less pollution. The denominator reflects that this reduction is limited, as it implies that marginal benefits increase and marginal damage is reduced.

Similarly, (7) expresses that more consumption in the past implies less consumption

⁶The second-order condition is fulfilled because $B'' < 0$, $Z'' > 0$.

today: Due to the convexity of the damage function, a larger inherited stock means a higher marginal cost of additional second-period pollution. Moreover, we can use this derivative to determine the effect of higher first-period consumption on total pollution in the second period:

$$\frac{\partial S_2^y(E_1, \kappa_y)}{\partial E_1} = \frac{\partial E_2^y(E_1, \kappa_y)}{\partial E_1} + (1 - \delta) = \frac{-B''(E_2^y)}{-B''(E_2^y) + \kappa_y Z''(S_2^y)}(1 - \delta) \in (0, 1 - \delta). \quad (8)$$

To understand (7) and (8), suppose that the second-period government inherits one more unit of pollution. One extreme reaction would be to stick with the original level of consumption. However, this would imply increased marginal damage costs, while marginal consumption benefits would remain the same, which cannot be optimal. The other extreme would be to fully compensate for the larger stock by foregoing the same amount of consumption. But neither can this be optimal, as it would keep marginal damage costs constant while increasing marginal consumption benefits.

Thus, one more unit of first-period consumption leads to $1 - \delta$ additional units of inherited stock pollution in the second period, which makes the second-period government reduce consumption by less than $1 - \delta$. To determine the effect on total second-period pollution in (8), we have to take the additional inherited unit of pollution from the first period and subtract the consumption reduction in the second: The second-period stock is increased by less than $1 - \delta$ units.⁷

The second-period government's optimal choice can be used to formulate that period's indirect consumption benefit function, indirect damage function, and the indirect utility function for each Party $i \in \{x, y\}$, given κ_y . We denote these indirect functions by the period superscript:

$$B^2(E_1, \kappa_y) \equiv B(E_2^y(E_1, \kappa_y)), \quad (9)$$

$$Z^2(E_1, \kappa_y) \equiv Z(S_2^y(E_1, \kappa_y)) = Z(E_2^y(E_1, \kappa_y) + (1 - \delta)S_1), \quad (10)$$

$$u^{i,2}(E_1, \kappa_y) \equiv B^2(E_1, \kappa_y) - \kappa_i Z^2(E_1, \kappa_y). \quad (11)$$

3.3 Consumption in the First Period

In the first period, Party x is in power. Substituting the second-period indirect utility function (11) for $i = x$ into (3), we obtain the Party's intertemporal utility as a function

⁷Limiting cases are defined by a linear damage function or a linear benefit function. In the former case, the amount of inherited pollution does not affect its marginal cost, so that consumption is not reduced. In the latter case, consumption reduction does not affect marginal benefits. Then, $t = 2$ pollution is kept constant and $t = 2$ consumption is reduced one-for-one. In both cases, the strategic effects analyzed in the model vanish. We therefore assume a strictly concave consumption utility function and a strictly convex pollution cost function, which does not seem to be a severe restriction.

of its own consumption choice and its successor's preference parameter:

$$\Psi^x(E_1, \kappa_y) = u_1^x(E_1) + u^{x,2}(E_1, \kappa_y). \quad (12)$$

Maximizing by choosing E_1 implies the following first-order condition:

$$\frac{\partial \Psi^x(E_1, \kappa_y)}{\partial E_1} \equiv u_1^{x'}(E_1^{x\#}) + \frac{\partial u^{x,2}(E_1^{x\#}, \kappa_y)}{\partial E_1} = 0, \quad (13)$$

where $E_1^{x\#}$ denotes the *strategic-optimum* consumption level of Party x . Substituting (1) and (5) into (13) and rearranging yields:

$$B'(E_1^{x\#}) = \kappa_x \left\{ Z'(S_1^{x\#}) + Z'(S_2^y) \left[1 - \delta + \frac{\kappa_x - \kappa_y}{\kappa_x} \frac{\partial E_2^y(E_1^{x\#}, \kappa_y)}{\partial E_1} \right] \right\}. \quad (14)$$

For the second-order condition, $\partial^2 \Psi^x(E_1, \kappa_y) / \partial E_1^2 < 0$, to hold, we assume:

Assumption 1. $B(E)$ and $Z(S)$ are either both quadratic or both exponential functions.

In Appendix A.1, I demonstrate that this assumption implies $\partial^2 E_2^y(E_1, \kappa_y) / \partial E_1^2 = 0$, which in turn is sufficient for the second-order condition to hold.⁸

In order to understand (14), first consider the natural benchmark that the governments of both periods have identical preferences, $\kappa_y = \kappa_x$. The first-order condition simplifies to:

$$B'(E_1^{x*}) = \kappa_x [Z'(S_1^{x*}) + Z'(S_2^x) (1 - \delta)], \quad (15)$$

where E_1^{x*}, S_1^{x*} denote the *identical-preferences optimum* consumption level of the first-period Party- x government (and the corresponding amount of pollution); today's marginal consumption benefit has to balance today's and tomorrow's marginal cost of pollution. (15) implicitly defines E_1^{x*} as a function of the valuation parameter κ_x . Differentiating and rearranging yields:

$$\frac{\partial E_1^{x*}(\kappa_x)}{\partial \kappa_x} = - \frac{Z'(S_1^{x*}) + Z'(S_2^{x*}) \partial S_2^{x*}(E_1^{x*}, \kappa_x) / \partial E_1}{-\partial^2 \Psi^x(E_1^{x*}, \kappa_x) / \partial E_1^2} < 0. \quad (16)$$

First-period consumption causes environmental damage in the first period. The first term in the numerator of (16) reflects that this damage is valued higher, which calls for reduced consumption. Additionally, first-period consumption causes environmental damage in the second period, which is also valued higher; the second term in the numerator represents this effect, and takes into account that what matters is the

⁸A necessary condition would restrict the behavior of the functions in optimum and could be fulfilled by other functional forms as well (see Appendix A.1). I assume the functional forms in Assumption 1 for concreteness.

equilibrium reduction of the whole second-period stock of pollution, including the reduced consumption in the second period. From (8) we know that the derivative of the second-period stock with respect to first-period consumption is positive. Thus, the whole derivative in (16) is negative, which is what we would intuitively expect.

Now consider (14) again. With differing preferences, the second-period government will not choose consumption optimally from the first-period government's perspective. Hence, the first-period government has to take the impact of its choice on second-period consumption and on the second-period stock of pollution into account. How does the strategic optimum compare to the identical-preferences optimum?

Suppose, for example, that today's government is green and tomorrow's is conservative, $\kappa_y < \kappa_x$. A conservative government will always consume more than a green one, given the size of the inherited pollution stock – see (6). Thus, the second-period marginal damage factor in (14), $Z'(S_2^y)$, becomes larger, *ceteris paribus*. The larger marginal damage costs on the right-hand side imply larger marginal benefits on the left-hand side, which means that consumption must be smaller. To put it another way, the Greens should consume less today, because each unit of pollution that they leave behind adds to a larger stock of pollution chosen in the future, and damage costs are convex in the stock. Additional to this direct effect of the change of government, there is an indirect effect. If the Greens leave behind more pollution, this makes the second-period government reduce consumption, which *ceteris paribus* reduces second-period pollution. This strategic interaction is represented by the product within in the square brackets in (14). The derivative term is negative – see (7) – so that the product is negative as well. Thus, the two effects work into opposite directions.

To find the dominant effect, we apply comparative statics. If Party y is known to take over, then the Party- x government's strategic-optimum consumption is a function of the valuation parameter of Party y , $E_1^{x\#}(\kappa_y)$. Thus, we can analyze how the first-period government behaves if it expects a second-period government with any given preferences. Differentiating (13) and rearranging yields:

$$\frac{\partial E_1^{x\#}(\kappa_y)}{\partial \kappa_y} = \frac{\partial^2 u^{x,2}(E_1^{x\#}, \kappa_y)}{\partial E_1 \partial \kappa_y} \bigg/ \left[-\frac{\partial^2 \Psi^x(E_1^{x\#}, \kappa_y)}{\partial E_1^2} \right]. \quad (17)$$

By the second-order condition, the denominator of this fraction is positive. Thus, (17) just tells us that a higher pollution aversion of Party y will make the Party- x government in the first period consume more if the marginal second-period utility of E_1 , as given by the indirect utility function (11), is increasing in κ_y . To find out whether it is, we

differentiate (11), and obtain after rearranging:

$$\frac{\partial^2 u^{x,2}(E_1^{x\#}, \kappa_y)}{\partial E_1 \partial \kappa_y} = \frac{\kappa_y - \kappa_x}{\kappa_y} \times \left[\underbrace{\frac{\partial E_2^y(E_1^{x\#}, \kappa_y)}{\partial \kappa_y}}_{<0} \underbrace{\frac{\partial E_2^y(E_1^{x\#}, \kappa_y)}{\partial E_1}}_{<0} \underbrace{B''(E_2^y)}_{<0} + \frac{\partial^2 E_2^y(E_1^{x\#}, \kappa_y)}{\partial E_1 \partial \kappa_y} B'(E_2^y) \right], \quad (18)$$

which states that the effect of a higher κ_y on the marginal second-period utility of E_1 for Party x is the relative κ difference multiplied by a sum of, firstly, its direct effect on the second-period choice, multiplied by the impact of first-period consumption on that choice, weighted by the steepness of the benefit curve (if it is steep, marginal utility is affected relatively more), plus, secondly, the change in the first-period government's influence on the second-period government's choice multiplied by the gained (or lost) marginal benefit. (18) directly allows a first conclusion to be drawn on the behavior of first-period consumption:

Lemma 1. *For identical preferences ($\kappa_y = \kappa_x$), the $E_1^{x\#}$ function has a stationary point: $\partial E_1^{x\#}(\kappa_x)/\partial \kappa_y = 0$.*

Moreover, because Assumption 1 constrains the admissible utility and damage functions, we can sharpen the characterization of $E_1^{x\#}(\kappa_y)$:⁹

Proposition 1. *If Assumption 1 holds, $u^{x,2}(E_1^{x\#}, \kappa_y)$ and, thus, $E_1^{x\#}(\kappa_y)$ have a maximum for $\kappa_y = \kappa_x$.*

Proof. See Appendix A.2. □

Proposition 1 is the core result of this paper. It states that the economy's consumption chosen by the first-period government is highest if the governing party stays in power – or, equivalently, if the second-period government has the same preferences. Both expecting a greener or a more conservative successor reduce optimal consumption compared to the identical-preferences situation.

It thus seems that of the effects described above, the direct effect is dominant for Greens expecting a conservative successor, while the indirect effect is dominant for Conservatives expecting a green successor. The key to understanding this is the different

⁹Again, quadratic or exponential functions are sufficient, but other functions could also imply Proposition 1. The necessary requirement is that the last square-bracketed term in (18) – the cross derivative – is either negative or sufficiently small so as not to change the sign of the whole term. The reason for such an additional requirement is that the first-period government cannot choose the value of both variables affecting its utility; in second-best problems like this, the usual envelope conditions do not hold and we need assumptions on third derivatives (cf. Lipsey and Lancaster, 1956–1957).

reaction of second-period consumption and pollution to the pollution stock left behind in the first period, (7) and (8).

For example, let us again consider a green government that expects a more conservative successor ($\kappa_y < \kappa_x$). If Party x were to ignore its loss of power in the next period, Party y would choose a large amount of consumption, so that pollution in the second period would become very substantial. From the Party- x point of view, marginal costs would exceed marginal benefits. The Party- x government therefore reduces first-period consumption (and, thus, foregoes some net utility in the first period). As we know from (7) and (8), Party y will then choose an even larger amount of consumption, but the increase will be less than proportional so that the total stock of pollution in the second period is smaller.¹⁰ For Party x , this reduces the gap between marginal costs and marginal benefits.

Now consider the opposite situation; the first-period incumbent anticipates a greener successor ($\kappa_y > \kappa_x$). If the Conservatives ignore the fact that they will lose power, the Greens in the second period inherit a lot of pollution and thus they drastically reduce consumption (because they allow only minimal additional pollution). However, this has a high opportunity cost for the Conservatives; they find the Greens' consumption too low for any level of inherited pollution. The Conservatives perceive the marginal benefit of the amount of consumption chosen by the Greens as higher than the marginal pollution cost. Reducing first-period consumption thus makes sense because it makes the second-period government allow more consumption.

Thus, the first-period government reduces consumption in that period if it expects to be voted out, but the motivation for this depends on the successor's preferences. If the expected future government is more conservative than the present one, it makes sense to directly reduce future pollution, but if it is greener, the present government will want to indirectly increase future consumption. In both cases, this implies smoothing out net utility between periods. To put it another way, the change in power and the perceived deviation from optimality raise the second-period cost of first-period consumption. If $\kappa_y < \kappa_x$, any unit of pollution left behind by the Greens in the first period adds to the large stock of pollution that the Conservatives will allow. If $\kappa_y > \kappa_x$, any unit of pollution left behind by the Conservatives in the first period further reduces the small amount of consumption that the Greens choose.

3.4 The Consequences of the Strategic Choice for the Parties

It is bad for Party x that Party y takes over in the second period, and adjusting the consumption choice to $E_1^{x\#}$ is the best that the Party- x government can do to mitigate

¹⁰This also implies more consumption benefits in the second period – but from the Greens' point of view, the second-period government still chooses too much consumption (and pollution), not too little.

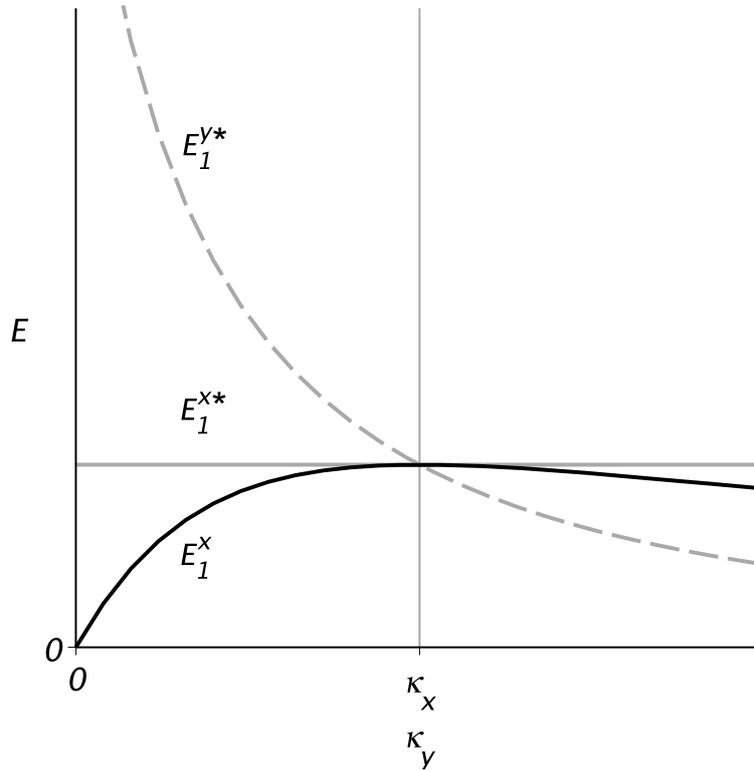


Figure 1: First-period consumption choices, depending on κ_y .

the effects. But is this adaptation good or bad for Party y ?

To answer this question, consider the point of view of the Party- y opposition in the first period. It knows that it will come to power in the future, so that the consumption level it would find optimal is its identical-preferences optimum, E_1^{y*} . Equivalently to (15), it is defined by the following first-order condition:

$$B'(E_1^{y*}) = \kappa_y [Z'(S_1^{y*}) + (1 - \delta) Z'(S_2^{y*})]. \quad (19)$$

The actual outcome of the political process can be judged in comparison to both parties' identical-preferences optimum levels. I demonstrate this with the aid of a diagram.¹¹ Along the horizontal axis of Figure 1, there are different values of κ_y . In the center, $\kappa_y = \kappa_x$, while to the right of the center, $\kappa_y > \kappa_x$ so that the second-period government is greener than the first-period incumbent (and vice versa). The three different curves show how κ_y determines the three different levels of first-period consumption discussed above.

The gray curves are the identical-preferences optimum levels. Firstly, the gray solid horizontal line is the identical-preferences consumption level of Party x , E_1^{x*} , as defined by (15). This would be the optimal choice of Party x if it would remain in power. The

¹¹The functions used for the diagram are quadratic and are stated in Appendix A.3.

curve is flat because the preferences of the opposition are irrelevant for the Party- y government in this case. Secondly, the dashed curve represents E_1^{y*} as defined by (19). The curve has a negative slope because a greener party would consume less – see (16). Finally, the black curve is the strategic-optimum consumption level $E_1^{x\#}(\kappa_y)$, as defined by (14). As discussed above, it has a maximum for identical preferences.

Consider some κ_y smaller than κ_x , which implies that the current government expects its conservative opposition to come to power in the future. This opposition would prefer a consumption level greater than E_1^{x*} . In the figure, this is reflected by the fact that the dashed curve in the left half lies above the horizontal line, and the difference grows with the κ difference. By contrast, the actually chosen consumption level $E_1^{x\#}(\kappa_y)$ is even lower than E_1^{x*} ; the black curve is downward-sloping to the left of $\kappa_y = \kappa_x$. This is the result discussed in the previous section – that the anticipation of a conservative successor leads to a reduction of first-period consumption. The outcome is inefficient: The green government escalates the disjunction between the opposition's demands and the government's actions and chooses a consumption level that none of the parties would prefer to E_1^{x*} .

By contrast, the right half of the figure shows what happens when a conservative incumbent anticipates a green successor. The dashed curve shows that the Greens' preferred level E_1^{y*} is lower than E_1^{x*} , but now, the black curve lies between the gray ones. Accordingly, the level actually chosen by the Conservatives is a compromise between the parties' wishes.¹²

Thus, expecting a greener or a more conservative successor has a symmetric effect on the incumbent's behavior – each of these differences leads to a consumption reduction. This reduction in turn leads to an asymmetric effect on the utility of the respective opposition. In the $\kappa_y > \kappa_x$ case, we have a conservative incumbent choosing a compromise level of consumption due to the expectation of losing power to a greener successor. Being a compromise, the Greens must prefer this compromise level to the identical-preferences choice of the conservatives. Moreover, it appears as though the conservatives have turned green, even though their preferences have not changed (only those of the future government have). In the reversed case, $\kappa_y < \kappa_x$, the incumbent also reduces consumption, so the Greens become greener – or more radical from the Conservatives' point of view. Party y would prefer the identical-preferences consumption level of the Party- x government to the actually chosen one.¹³

¹²Mathematically, this has to be the case because for $\kappa_y = \kappa_x$, E_1^{y*} has a negative slope, while $E_1^x(\kappa_y)$ has a zero slope at its maximum, i. e., for $E_1^x(\kappa_x)$.

¹³As a side note, consider the Party- y leader's situation before $t = 1$, knowing that her party will be in power in $t = 2$. Would she prefer Party x to feel safe or would she like to let them know that they will be replaced? The answer is that it depends on whether Party y is greener than Party x . A green party would prefer the conservative incumbents to know that their days of government are numbered, and know their successor's preferences. This will lead the government to a compromise. By contrast, Conservatives would like to take power by surprise or, equivalently, they would like the Greens to believe

4 Further Issues

4.1 Binding Agreements

In the political environment of our model, the incumbent's choice of consumption is not only determined by utility-maximization per se, but also by influencing the successor's actions. This is rational in a non-cooperative environment. However, this suggests that a cooperative solution may improve the situation of both parties. How does it compare to the previously discussed non-cooperative solution?

Suppose that the parties bargain a binding agreement for consumption levels in both periods. The agreement values E_1° , E_2° are chosen so as to maximize the (asymmetric) Nash product \mathcal{N} :

$$E_1^\circ \in \arg \max_{E_1} \mathcal{N} = [U^x(E_1, E_2^\circ) - \Psi^{x\#}(\kappa_y)]^\mu [U^y(E_1, E_2^\circ) - \Psi^{y\#}(\kappa_y)]^{1-\mu}, \quad (20a)$$

$$E_2^\circ \in \arg \max_{E_2} \mathcal{N} = [U^x(E_1^\circ, E_2) - \Psi^{x\#}(\kappa_y)]^\mu [U^y(E_1^\circ, E_2) - \Psi^{y\#}(\kappa_y)]^{1-\mu}. \quad (20b)$$

μ is the bargaining weight, $\Psi^{x\#}$ is the Party- x utility function (12) maximized by the strategic E_1 choice, and $\Psi^{y\#}$ is the utility of Party y in the same situation:

$$\Psi^{x\#}(\kappa_y) \equiv u_1^x(E_1^{x\#}(\kappa_y)) + u^{x,2}(E_1^{x\#}(\kappa_y), \kappa_y), \quad (21a)$$

$$\Psi^{y\#}(\kappa_y) \equiv u_1^y(E_1^{y\#}(\kappa_y)) + u^{y,2}(E_1^{y\#}(\kappa_y), \kappa_y). \quad (21b)$$

Thus, both parties' utility would be defined by the non-cooperative policy of the previous section if they would not agree in the negotiation. The first-order conditions are

$$\omega_x \frac{\partial U^x(E_1^\circ, E_2^\circ)}{\partial E_1} + \omega_y \frac{\partial U^y(E_1^\circ, E_2^\circ)}{\partial E_1} = 0, \quad (22a)$$

$$\omega_x \frac{\partial U^x(E_1^\circ, E_2^\circ)}{\partial E_2} + \omega_y \frac{\partial U^y(E_1^\circ, E_2^\circ)}{\partial E_2} = 0. \quad (22b)$$

We can see that E_1 and E_2 are chosen as if to maximize a weighted sum of the parties' utility, where $\omega_x \equiv \mu / [U^x(E_1^\circ, E_2^\circ) - \Psi^{x\#}(\kappa_y)]$ and $\omega_y \equiv (1-\mu) / [U^y(E_1^\circ, E_2^\circ) - \Psi^{y\#}(\kappa_y)]$ are the respective weights. Thus, to fulfill (22), there must always be one party with positive marginal utility and one with negative marginal utility in each period; put another way, the Greens consider the cooperatively chosen consumption too high in each period, while the Conservatives consider it too low.

This compromise policy differs most markedly from the non-cooperative policy in the $\kappa_y < \kappa_x$ case. As we have seen above, the green first-period government chooses an

that their Party- y opposition has the same environmental-policy preferences as they do, because this keeps the government from escalating the political disjunction.

amount of consumption that is smaller than the identical-preferences optimal levels of the respective parties and thus cannot incorporate a compromise.

For the $\kappa_y > \kappa_x$ case, we have a compromise level of consumption both in the cooperative and in the non-cooperative optimization. However, given first-period consumption, the cooperative amount of consumption (for which marginal utility of the second-period government is negative) is larger than the non-cooperative amount (for which it is zero). For making this worthwhile for Party y , a stronger reduction in the first period has to be chosen in the cooperative solution than the one that the Conservatives would choose anyway.

At first glance, such compromise agreements seem to be merely theoretical solutions: Firstly, in real-world politics, elections should determine and enforce the majority's will and secondly, agreements would need to be conditional on many possible exogenous circumstances, which is often deemed too complex. However, there are examples of institutions finding compromise solutions between political parties, particularly with respect to environmental problems. The *Enquete-Kommissionen* (commissions of inquiry) of the German Bundestag are a good case in point. An Enquete-Kommission can be established on the orders of a parliamentary minority and it includes members of all parties, as well as external experts. Its function is to discuss questions of long-term importance. Of the 27 Enquete-Kommissionen that have existed since 1971, six more or less directly discussed the consumption-pollution trade-off considered in this article.¹⁴ While their recommendations may not have binding power, they may be the closest thing we have to credible agreements between parties.

4.2 Further Parameters

Suppose that we had chosen a probabilistic instead of a deterministic change of the governing party in the second period. Thus, Party x would expect to be able to choose second-period consumption with some probability, and expect a successor with different preferences with the respective counter-probability. Would this change the model results? The sign of the derivative in (17) does not depend on Party y taking power with certainty. While the quantitative strength of the strategic effect would change if we had to multiply the term by the probability of not being reelected, the qualitative implications would remain identical. Likewise, a higher probability of conceding the government to a successor with different preferences is equivalent to an increase in the preference difference if the probability is given. Thus, for example, Conservatives will

¹⁴These were: Enquete-Kommissionen 7, "Future Nuclear Policy", 9, "Technology Assessment", 12, "Provision for Protecting the Earth's Atmosphere", 15, "Protecting Mankind and the Environment", 24, "Sustainable Energy Supply against the Background of Globalization and Liberalization", and 27, "Growth, Wellbeing and Quality of Life – Ways to Sustainable Economic Activity and Social Progress in the Social Market Economy".

react similarly to an increased chance of a green electoral success due to an exogenous shock (like an environmental disaster) or to a preference shock in the green party, given probabilities.

A second parameter that is missing in the model is discounting. If the future is discounted, the impact on second-period consumption has less weight in choosing first-period consumption. While this surely has quantitative effects, there is no reason why it should qualitatively change the strategic effects derived in the model.

A parameter that I have included in the model is nature's regeneration rate δ ; it allows a qualitative empirical prediction that could be tested empirically. If we have instantaneous regeneration ($\delta = 1$), the problem is no longer one of stock pollution, and consumption in the first period does not influence the choice in the second – see (7). That is, Party x may not be happy with what Party y does, but it has no strategic lever to change it, and it does not have to take it into account in choosing first-period policy. Thus, the model predicts that for given environmental preferences of a government, an increased election chance of a party with different preferences would lead to a stricter environmental regulation for stock pollutants (like lake pollution), while there should be no effect for flow pollutants (like noise).

5 Conclusions

The model presented here shows how an incumbent expecting a successor with different preferences strategically chooses the level of consumption, knowing that the successor's choice will depend both on intrinsic preferences and on the inherited stock of pollution. It turns out that this expectation leads to reduced consumption (and pollution) today, no matter whether a greener or a more conservative successor is expected. Consumption is at its maximum if the successor has the same preferences as the incumbent.

Expecting a more conservative government in the future, a green incumbent reduces consumption in order to leave a smaller stock of pollution. This leads to higher future consumption, but as consumption is not increased one-to-one, the total stock of future pollution is reduced. A conservative government's situation is a mirror-image; it reduces consumption not to reduce future pollution per se, but to leave less pollution behind so that the Greens do not drastically reduce consumption. Thus, the model's main contribution is that it offers an explanation of why conservatives adopt environmentalist policies in some countries, even if politicians are policy-motivated instead of office-motivated. Their motive is to constrain the Greens' policy in the future, but they have not intrinsically "turned green". Moreover, we have seen that the Conservatives' choice of present pollution reflects a compromise position between the intrinsically pre-

ferred levels of the two parties. The Greens, by contrast, will escalate their policy if they anticipate a loss of power.

The model implies that the parties could be better off by agreeing on compromise levels of consumption and pollution for both the present and the future. At first glance, this seems irrelevant, as real-world parties in general do not sign binding agreements, but the case of German parliamentary *Enquete-Kommisionen*, discussed in the previous section, may be an example that political parties understand that it sometimes makes sense to compromise on environmental issues.

In future work building on this model, it may be most promising to analyze how the parties will behave in a fully dynamic setting. For example, it seems possible that political volatility leads to a slower convergence to a steady state of pollution. Additionally, as pointed out in the previous section, the described strategic effects depend on the pollutant being a stock pollutant – like river pollution or soil contamination¹⁵ – so that we should observe a different effect of expected political changes on different pollutants, depending on their longevity. This enables the model to be tested empirically.

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¹⁵Climate change is also a stock problem, but also an international one and thus our analysis is not easily transferable.

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A Appendix

A.1 The First-period Government’s Second-order Condition

To fulfill the sufficient condition for an optimum with the consumption level defined by (14), the second derivative of the first-period government’s utility function, $\partial^2 \Psi_1^x / \partial E_1^2$, must be negative. Differentiating the utility function of Party x , (13), twice and substituting the second-period optimality condition (5) yields

$$\begin{aligned} \frac{\partial^2 \Psi^x(E_1^x, \kappa_y)}{\partial E_1^2} = & B''(E_1^{x\#}) - \kappa_x Z''(S_1^{x\#}) + B''(E_2^y) \left[\frac{\partial E_2^y(E_1^{x\#}, \kappa_y)}{\partial E_1} \right]^2 \\ & - \kappa_x Z''(S_2^y) \left[\frac{\partial E_2^y(E_1^{x\#}, \kappa_y)}{\partial E_1} + (1 - \delta) \right]^2 \\ & + B'(E_2^y) \frac{\partial^2 E_2^y(E_1^{x\#}, \kappa_y)}{\partial E_1^2} \frac{\kappa_y - \kappa_x}{\kappa_y}. \end{aligned} \quad (\text{A.1})$$

Due to the concave benefit function and the convex cost function, all terms are unambiguously negative, except for the last summand. To determine its sign, we differentiate (7) and obtain after rearrangements:

$$\begin{aligned} \frac{\partial^2 E_2^y(E_1, \kappa_y)}{\partial E_1^2} = & \left[\frac{\partial E_2^y(E_1, \kappa_y)}{\partial E_1} \right]^2 [-B''(E_2^y) + \kappa_y Z''(S_2^y)]^{-1} \\ & \times \left\{ B'''(E_2^y) - \frac{1}{\kappa_y} \left[\frac{B''(E_2^y)}{Z''(S_2^y)} \right]^2 Z'''(S_2^y) \right\}. \end{aligned} \quad (\text{A.2})$$

The first factor is the square of a value smaller than $1 - \delta$, so that it is small and positive – see (7). The second factor is positive. Apart from that, however, it cannot be stated meaningfully how large this term is, because the size (and sign) of the third derivatives – and thus, of the second line – are unclear a priori. However, we can state a sufficient condition: (A.1) is negative if either both functions are quadratic or both are exponential, because both conditions imply

$$B'''(E_2^y) = \frac{1}{\kappa_y} \left[\frac{B''(E_2^y)}{Z''(S_2^y)} \right]^2 Z'''(S_2^y), \quad (\text{A.3})$$

which is necessary and sufficient for (A.2) to be zero. In the quadratic case, (A.3) is fulfilled because the third derivatives are zero. To see that (A.2) is zero at the optimum

with exponential functions, divide numerator and denominator of the fraction in (7) by $\partial Z/\partial S$ and substitute the optimality condition (5). For both B and Z , we obtain the respective semi-elasticity of the marginal function value, which is a constant for an exponential function.

A.2 The Sign of the Cross-partial Derivative of the Indirect Utility Function

For convenience, we rewrite (18) as follows:

$$\begin{aligned} \frac{\partial^2 u^{x,2}(E_1^{x\#}, \kappa_y)}{\partial E_1 \partial \kappa_y} &= \frac{\kappa_y - \kappa_x}{\kappa_y} \underbrace{\frac{\partial E_2^y(E_1^{x\#}, \kappa_y)}{\partial \kappa_y}}_{<0} \underbrace{\frac{\partial E_2^y(E_1^x, \kappa_y)}{\partial E_1}}_{<0} \underbrace{B''(E_2^y)}_{<0} \\ &\times \left[1 + \frac{\frac{\partial^2 E_2^y(E_1^x, \kappa_y)}{\partial E_1 \partial \kappa_y}}{\frac{\partial E_2^y(E_1^x, \kappa_y)}{\partial \kappa_y}} \frac{B'(E_2^y)}{\frac{\partial E_2^y(E_1^x, \kappa_y)}{\partial E_1} B''(E_2^y)} \right]. \end{aligned} \quad (\text{A.4})$$

We can simplify this equation using (A.3), which is implied by Assumption 1. To do so, we first need an expression for the cross-partial derivative in the second line. Differentiating (6) with respect to E_1 (and rearranging), we obtain:

$$\begin{aligned} \frac{\partial^2 E_2^y(E_1, \kappa_y)}{\partial E_1 \partial \kappa_y} &= \frac{\partial E_2^y(E_1, \kappa_y)}{\partial \kappa_y} \frac{\partial E_2^y(E_1, \kappa_y)}{\partial E_1} \\ &\times \left[\frac{B''(E_2^y)}{\kappa_y Z'(S_2^y)} + \frac{B'''(E_2^y) - Z'''(S_2^y) \frac{B''(E_2^y)}{Z''(S_2^y)}}{-B''(E_2^y) + \kappa_y Z''(S_2^y)} \right]. \end{aligned} \quad (\text{A.5})$$

Substituting (A.3) and (5), this simplifies to:

$$\frac{\partial^2 E_2^y(E_1, \kappa_y)}{\partial E_1 \partial \kappa_y} = \frac{\partial E_2^y(E_1, \kappa_y)}{\partial \kappa_y} \frac{\partial E_2^y(E_1, \kappa_y)}{\partial E_1} \left[1 - \frac{Z'''(S_2^y)/Z''(S_2^y)}{Z''(S_2^y)/Z'(S_2^y)} \right] \frac{B''(E_2^y)}{B'(E_2^y)}. \quad (\text{A.6})$$

Substituting (A.6) into (A.4) yields:

$$\begin{aligned} \frac{\partial^2 u^{x,2}(E_1^x, \kappa_y)}{\partial E_1 \partial \kappa_y} &= \frac{\kappa_y - \kappa_x}{\kappa_y} \underbrace{\frac{\partial E_2^y(E_1^x, \kappa_y)}{\partial \kappa_y}}_{<0} \underbrace{\frac{\partial E_2^y(E_1^x, \kappa_y)}{\partial E_1}}_{<0} \underbrace{B''(E_2^y)}_{<0} \\ &\times \left\{ 1 + \left[1 - \frac{Z'''(S_2^y)/Z''(S_2^y)}{Z''(S_2^y)/Z'(S_2^y)} \right] \right\}. \end{aligned} \quad (\text{A.7})$$

We can determine the sign of this derivative if the round-brackets term in the second line is always larger than -1 . While we cannot take this for granted in general, as-

sumption $1 - B$ and Z being either both quadratic or both exponential – is sufficient for determining the sign. For quadratic functions, the third derivative is zero, so that the second-line square-brackets term in (A.7) equals 2; for exponential functions, the ratio of the third derivative to the second is the same as the ratio of the third derivative to the first, so that the square-brackets term equals unity. In both cases, (A.7) is negative (positive) for $\kappa_y > \kappa_x$ ($\kappa_y < \kappa_x$).

A.3 Explicit Functions Used for the Diagrammatic Illustration

The following functions are used for Figure 1. The benefit function is $B = E - E^2/2$, the damage function is $Z = S^2/2$, so that the instantaneous utility function (1) becomes

$$u_t^i(E_t, S_t) \equiv E_t - \frac{1}{2}E_t^2 - \kappa_i \frac{1}{2}S_t^2. \quad (\text{A.8})$$

For second-period consumption and pollution, which are implicitly defined in equation (5), we then have

$$E_2^y(E_1, \kappa_y) = \frac{1}{1 + \kappa_y} [1 - \kappa_y(1 - \delta) [E_1 + (1 - \delta)S_0]], \quad (\text{A.9})$$

$$S_2^y(E_1, \kappa_y) = \frac{1}{1 + \kappa_y} [1 + (1 - \delta) [E_1 + (1 - \delta)S_0]]. \quad (\text{A.10})$$

Using this in (12) and optimizing with respect to E_1 , we can derive $E_1^{x\#}(\kappa_y)$, which is:

$$E_1^{x\#}(\kappa_y) = \frac{(1 + \kappa_y)^2 - (1 - \delta) \left[(\kappa_x + \kappa_y^2) + [(\kappa_x + \kappa_y^2)(1 - \delta)^2 + \kappa_x(1 + \kappa_y)^2] S_0 \right]}{(\kappa_x + \kappa_y^2)(1 - \delta)^2 + (1 + \kappa_x)(1 + \kappa_y)^2}. \quad (\text{A.11})$$

Differentiating yields

$$\frac{\partial E_1^{x\#}(\kappa_y)}{\partial \kappa_y} = \frac{2(1 + \kappa_y)(1 - \delta) [1 + \kappa_x + (1 - \delta) [1 + (1 - \delta)S_0]]}{\left[(\kappa_x + \kappa_y^2)(1 - \delta)^2 + (1 + \kappa_x)(1 + \kappa_y)^2 \right]^2} (\kappa_x - \kappa_y). \quad (\text{A.12})$$

Because $1 \geq \delta \geq 0$, this derivative is positive for $\kappa_y < \kappa_x$, zero for $\kappa_y = \kappa_x$ and negative for $\kappa_y > \kappa_x$, just as we should expect from the discussion in Section 3.3. Now consider the identical-preferences optimum of Party y , $E_1^{y*}(\kappa_y)$ as in equation (19). It can be obtained from (A.11) by substituting $\kappa_x = \kappa_y$. Simplifying then yields:

$$E_1^{y*}(\kappa_y) = \frac{1 + \kappa_y - (1 - \delta) \kappa_y [1 + [(1 - \delta)^2 + 1 + \kappa_y] S_0]}{\kappa_y (1 - \delta)^2 + (1 + \kappa_y)^2}. \quad (\text{A.13})$$

Differentiating yields

$$\frac{\partial E_1^{y*}(\kappa_y)}{\partial \kappa_y} = - \frac{\left[(1 - \delta)^2 + (1 + \kappa_y)^2 \right] \left[1 + (1 - \delta) S_0 \right] + (1 - \delta) (1 - \kappa_y^2)}{\left[\kappa_y (1 - \delta)^2 + (1 + \kappa_y)^2 \right]^2}. \quad (\text{A.14})$$

This derivative is negative – as discussed in Section 3.3 – if the square-brackets terms is positive. As $1 \geq \delta \geq 0$, this is fulfilled for any positive κ_y .