

# Escaping the Climate Trap? Values, Technologies, and Politics\*

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## Abstract

It is widely acknowledged that reducing emissions of greenhouse gases is almost impossible without radical changes in consumption patterns and the structure of production. This paper examines the interdependent roles of changing environmental values, changing technologies, and the politics of environmental policy, in creating sustainable societal change. Complementarities that emerge naturally in our framework may generate a “climate trap,” where society does not transit towards lifestyles and technologies that are more friendly to the environment. We discuss a variety of forces that make the climate trap more or less avoidable, including lobbying by firms, private politics, motivated scientists, and (endogenous) subsidies to green innovation.

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# 1 Introduction

What will it take to bring about the fourth industrial revolution that may be needed to save the planet? Such a revolution would require major structural changes in production as well as consumption patterns. Firms would have to invest on a large scale in technologies that generate lower greenhouse-gas emissions, and households would have to turn their consumption to goods that produce lower emissions.

These observations suggest that the required transformation entails a basic complementarity akin to the one associated with so-called platform technologies (Rochet and Tirole 2003). If green technologies became more attractive, people would be more likely to adopt values that promote environmentally friendly lifestyles. And if more people were changing their lifestyle, firms would indeed be more likely to develop those green technologies. We might thus see complementarities drive a two-way dynamic between values and technologies.

Government intervention is bound to be key in such a major transformation.<sup>1</sup> But studying exogenous government policies, or looking for optimal policy paths chosen by benevolent, far-sighted social planners, leaves the analysis of interventions seriously incomplete. Without studying politics, we will not know the circumstances under which endogenously chosen climate policies lead in the right direction. Thus we must understand how incentive-compatible policies are formed, by taking into account not only current political objectives but also the inability of incumbents to commit their successors to future policies.

This paper is a first step towards exploring the economic and political conditions for a two-sided green transition. We study the joint dynamics of environment-friendly values and technologies from two stepping stones. One is a model of values and environmental taxation, as in Besley and Persson (2019a), where people who identify as environmentalists change not just their consumption patterns but also their policy preferences. But we marry this with a model of endogenous technological change for green or brown technologies along the lines of Acemoglu et al (2012).<sup>2</sup> The resulting dynamic

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<sup>1</sup>See OECD (2010) for a discussion of how fiscal instruments, i.e. taxes and subsidies are used.

<sup>2</sup>One key difference is that their model focuses on intermediate goods (energy), while ours focuses on final goods. Another is that they work with a single representative consumer, while we allow for preference dynamics due to evolving consumer values. A third

model has three elements which coevolve: technologies, values, and political decisions.

We highlight the role of political mechanisms. Our baseline model is dramatically simplified, with (aside from consumption choices) voting the only expression of preferences of the currently alive. But we enrich this framework to study a broader range of political influence by activists or scientists (acting as members of civil society) and via lobbying by firms. By considering these wider pathways to influence, we can gain sharper insights into how *political* change can support or block economic change.

Our analysis brings good and bad news. A path of changing values can support structural change towards predominantly green technologies. But this outcome is by no means guaranteed. The complementarities between technology and values, mediated by politics, imply that society may or may not cross a tipping point, which makes the future virtuous or viscous. We articulate precisely – through divergent dynamics – how a society can be stuck in a climate trap. In such a trap, a long-run transition from “business as usual” to a low-pollution economy is possible, but does not occur because of how politics, technology, and values interact.

The remainder of the paper is organized as follows. Section 2 explains how our approach relates to earlier research in a number of different literatures. We then develop our framework step by step. Section 3 lays out the baseline economic model, which has building blocks for the static decisions in consumption and production. Section 4 analyzes dynamic choices regarding socialization and innovation, introduces our baseline political modeling, and shows how corrective taxation is determined in two-party electoral competition. This section also derives the full-equilibrium dynamics – in terms of both economics and politics – for values and technologies. It shows that these dynamics are divergent, and can lead to either a green or a brown steady state, where the latter can be viewed as a climate trap with lower welfare. Finally, we discuss the comparative dynamics implied by the model.

The baseline model is built to illustrate our initial complementarity mechanism in as simple a way as possible. This minimalist structure embodies restrictive assumptions about the actions available to households, firms, and political parties. Section 5 extends the model to allow for richer behavior of these agents. The extensions all pick up salient points in recent discussions

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key difference is that they consider exogenous policies, whereas we consider endogenous policymaking.

about the climate problem. Thus, we let citizens act upon their values, not just as consumers but also as innovators, and not just in public politics (as voters) but also in private politics (outside the electoral process). We also allow firms to act not just in the economic but also in the political sphere (by lobbying politicians). Finally, we equip politicians with additional policy instruments which allow them to influence firm-level decisions both in the present and in the future (and thus, indirectly, future policies). Section 6 takes stock of the results and concludes. Some proofs and supplementary materials are relegated to an Appendix.

## 2 Antecedents

This paper is related to different lines of research in economics and the social sciences more broadly. In the interests of brevity, we merely mention these strands of work, rather than attempting an exhaustive literature review.

There are many theoretical models of endogenous technological change. Innovation can be classified into one of three main categories: firms innovating to produce new goods as in Romer (1990), new firms displacing old firms in the production of existing goods as in Aghion and Howitt (1992), and innovations by existing firms in the production of existing goods as in Krusell (1998). Our model follows the third approach. Garcia-Macia, Hsieh, and Klenow (2019) discuss these different forms of innovation and find that the improvement of existing goods by existing firms is the most important source of U.S. technological change.

A growing literature studies the drivers of innovation in green versus brown technologies. These papers draw on theoretical findings by Acemoglu (2002) on directed, endogenous technical change, and empirical findings by Popp (2002) on links from energy prices to energy-saving investments. Acemoglu et al (2012) is an early theoretical contribution, with later work by Acemoglu et al (2016), Aghion et al (2016), and many others. Unlike this research, which focuses on green and brown technologies to produce intermediate goods, especially energy, we focus on green and brown technologies to produce final-consumption goods.

Our paper is also related to research on policies to fight climate change. A classic approach builds on extensions of the neoclassical growth model like Nordhaus and Boyer (2000) and, more recently, Golsosov et al (2014). These models add a simple carbon-cycle and global-warming bloc, such that emis-

sion of greenhouse gases enduringly damages society. They study a social planner, who maximizes an exogenous objective function under full commitment, to derive a sequence of policies, typically for carbon taxes (see Hassler and Krusell 2018 for an overview).

Our model abstracts from mechanisms whereby greenhouse-gas emissions impose enduring effects on the climate. But it allows for a richer analysis of policymaking, by endogenously deriving optimal and credible policies in a simple model of political competition. While stylized, it illustrates policy-shaping forces stressed in the political-economics literature, such as electioneering and lobbying. Lacking commitment is natural: politicians can rarely bind their successors, as illustrated when President Trump pulled out of the Paris accord. This does not rule out strategic policy making to affect future policy outcomes, as in the so-called strategic-debt literature (e.g., Persson and Svensson 1989, Tabellini and Alesina 1990), which is the subject of one of our extensions in Section 5.

Standard approaches to the politics of environmentalism (see Oates and Portney 2003 for a review) suppose that underlying values and preferences are fixed and are mostly static. As well as voting, they have also studied how interest groups lobby policymakers to move policy in their preferred direction, which is something we consider in a further extension of the baseline model.

Yet another strand of research investigates “private politics,” where activists pressure firms directly for change outside of the political system. This is particularly important in actions against polluting firms and firms involved in fossil-fuel production (see Abito et al 2019 for a review). We use an extension of our baseline framework to show how such activities can influence an economy’s dynamic path.

The paper encompasses ideas from the literature on endogenous cultural change when we suppose that values are responsive to developing policies and technologies. While the links between values and pollution taxes were explored already in Besley and Persson (2019a), this paper combines them with directed technological change.<sup>3</sup> A related model with a nationalistic – rather than a green – dimension of politics appears in Besley and Persson (2019b).

Our approach to changing values is rooted more generally in an earlier literature on cultural evolution beginning with Boyd and Richerson (1985)

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<sup>3</sup>Mattauch et al (2018) also consider policy implications with a form of endogenous values.

and Cavalli-Sforza and Feldman (1981) – Bisin and Verdier (2011) review economic applications. The present paper is related to Nyborg et al (2006), who study how green consumers emerge in a model of pro-social motivation modeled as self-image.

When values change, people may alter their economic and policy preferences. Following Akerlof and Kranton (2000), we view this through the lens of identity formation, with environmentalists and materialists forming two identity groups. While this approach has a long history in sociology and social psychology, it has only recently gained currency in economics.<sup>4</sup>

### 3 The Economic Model

This section formulates the core elements of our baseline economic model. By short overview, this model has two continua of monopolistically competitive firms: one producing varieties of brown (polluting) goods, another producing varieties of green (non-polluting) goods. Consumers are of two types: environmentalists and materialists who have (starkly) different consumption patterns.

**Goods, consumers, and types** A numeraire good  $x$  can be transformed into two kinds of goods. We label these green and brown, as the former kind does not pollute the environment but the second kind does. A continuum of green goods is indexed by  $i \in [0, 1]$ . The quantity, quality, price, and tax rate on green variety  $i$  are denoted by  $\{y(i), q(i), p(i), t(i)\}$ . Similarly, a continuum of brown goods is indexed by  $j \in [0, 1]$ , with a corresponding quadruple of variables  $\{Y(j), Q(j), P(j), T(j)\}$ .

We will focus on a case with complete symmetry within sectors, where all brown and all green firms take the same actions, and are all facing the same tax rates,  $T$  and  $t$  respectively.

Only one generation at a time is economically active. In any given period, the size-one mass of citizens is divided into two types  $\tau$ , namely environmentalists  $\tau = e$ , and materialists,  $\tau = m$ . These types represent consumers who have identified with different values. Variable  $\mu \in [\underline{\mu}, \bar{\mu}]$  denotes the share of environmentalists, where  $\underline{\mu}$  is a lower bound and  $\bar{\mu}$  an upper bound with  $\bar{\mu} > 1/2 > \underline{\mu}$ . We take these bounds as capturing historical-cultural forces

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<sup>4</sup>See Bowles (1998) for a general discussion of preference change in economic models.

outside of the model. As we discuss extensively below, this share changes over time, as new generations are socialized into holding alternative values.

Each consumer has a fixed income of  $M$  (to be determined below), in terms of the numeraire. The two consumer types vary according to their consumption values with environmentalists (materialists) only valuing green (brown) goods.<sup>5</sup>

Demand patterns in society will change over time to the extent environmental values change among consumers, inducing them to demand different goods. This model captures the notion of changing lifestyles in an alternative (and in our view superior) way to the conventional model with fixed utility functions, where changes in demand patterns are solely due to substitution between goods induced by price and quality incentives. Moreover, the discussion and data in Besley and Persson (2019b) suggest that environmental values vary considerably across countries and age cohorts.

**Materialists** Materialists have preferences

$$\begin{aligned} U &= x + \frac{1}{1-\sigma} \int_0^1 Q(j) Y(j)^{1-\sigma} dj - \lambda \int_0^1 \bar{Y}(j) dj \\ &= x + \int_0^1 \frac{QY^{1-\sigma}}{1-\sigma} dj - \lambda \int_0^1 \bar{Y} dj, \end{aligned}$$

with  $\sigma < 1$ . In this expression,  $\lambda > 0$  measures the dislike for (damages of) pollution, a barred variable denotes an average value in the population, and the lower-line expression takes advantage of the symmetry assumption. Materialists maximize these preferences subject to

$$M \geq x + \int_0^1 (P + T)Y dj + \int_0^1 (p + t)y di. \quad (1)$$

A single materialist consumer cannot affect the aggregate pollution level with his own behavior, and thus ignores the effect of his consumption on  $\bar{Y}$ . Pollution is thus a classic externality.

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<sup>5</sup>Obviously, the assumption that each type only values a single type of goods is very strong and made for convenience only. A systematic difference across types in their preferences for green and brown goods is all we need to make the same (qualitative) points.

Trivially, no materialist consumer buys any green goods – they cost money without generating utility benefits.<sup>6</sup> Individual demand for a typical brown-good variety becomes

$$Y = \left( \frac{P + T}{Q} \right)^{-\frac{1}{\sigma}}, \quad (2)$$

with an economy-wide demand of  $(1 - \mu)Y = \bar{Y}$ . Note that a higher quality  $Q$ , and a lower price-quality ratio, encourages more consumption of the brown good.

**Environmentalists** Environmentalists have preferences

$$\begin{aligned} u &= x + \frac{1}{1 - \sigma} \int_0^1 q(i) y(i)^{1 - \sigma} di - \lambda \int_0^1 \bar{Y}(i) dj \\ &= x + \int_0^1 \frac{qy^{1 - \sigma}}{1 - \sigma} di - \lambda \int_0^1 \bar{Y} dj \end{aligned}$$

and face the same budget constraint (1) as do brown consumers. They do not buy brown goods and have a demand for each green-good variety of

$$y = \left( \frac{p + t}{q} \right)^{-\frac{1}{\sigma}}. \quad (3)$$

Environmentalist consumers – individually or collectively – have no direct effect on pollution, but for the important fact that they only consume green goods which do not contribute to it.

**Firms** To model innovation incentives, suppose that every green-goods and brown-goods variety is supplied by a monopolist at a constant marginal cost  $\chi$ . In the baseline model, firms care only about their own profit. Firms are infinitely-lived institutions, which are run by successive generations of managers who maximize long-run profits in every period. Firms are owned by consumers to whom profits are distributed.

The profit function for the typical brown-variety firm is

$$(1 - \mu) [QY^{1 - \sigma} - (\chi + T)Y].$$

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<sup>6</sup>An alternative would be to model materialists as unconcerned with the environment and just buying goods with favorable price-quality ratios to the extent they confer similar consumption benefits.

Choosing output – and thus the mark-up price – to maximize profit yields

$$Y = \left[ \frac{\chi + T}{(1 - \sigma) Q} \right]^{-\frac{1}{\sigma}}.$$

As in standard models, monopoly power makes profit-maximizing firms produce below the social optimum by charging a price above marginal cost. Maximized profits per firm are

$$\Pi(Q, T, \mu) = (1 - \mu) \sigma Q K(T), \quad (4)$$

where  $K(T) = [(\chi + T) / (1 - \sigma)]^{1 - \frac{1}{\sigma}}$ . The fact that profits are scaled by  $1 - \mu$  reflects a market-size effect: having more materialists raises profits for the goods they consume. This will also drive the innovation incentives studied below. Higher quality also enhances profits, while a higher brown-goods tax rate reduces them.

An analogous argument for green firms yields

$$\pi(q, t, \mu) = \mu \sigma q k(t), \quad (5)$$

where  $k(t) = [(\chi + t) / (1 - \sigma)]^{1 - \frac{1}{\sigma}}$ . Now,  $\mu$  represents the market-size effect related to the share of environmentalists.

**Innovation** Any existing brown (green) firm can invest in improving the quality of its variety by hiring  $N$  ( $n$ ) inventors/scientists as in Krusell (1998).<sup>7</sup> We assume that a fraction  $\Omega$  of the population can train to become inventors/scientists at psychic cost  $\omega$ , and contract to work for a firm at the point of training. In effect,  $\omega$  is the cost of hiring a scientist as long as some eligible non-scientists remain – i.e.,  $(1 - \mu) \int_0^1 N dj + \mu \int_0^1 n di < \Omega$ . (When considering the dynamics in the next section, we assume that this condition holds.)

By recruiting scientists, the firm increases its (next-period) product quality to

$$q \left[ 1 + \left( \frac{n}{q_s} \right)^\varphi \right] \quad \text{and} \quad Q \left[ 1 + \left( \frac{N}{Q} \right)^\varphi \right].$$

Since  $\varphi < 1$ , inventive activity has decreasing returns. We consider optimal innovation behavior below.

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<sup>7</sup>In his model, though, inventors work on improving intermediate goods that serve as inputs to produce (a single form of) final goods.

**Public finance** As in most existing analyses of Pigouvian taxation, we abstract from redistributive issues and assume that all tax proceeds are paid back to consumers on a per-capita basis.<sup>8</sup> In other words, the government budget constraint is

$$T(1 - \mu) \int_0^1 Y dj + t\mu \int_0^1 y di = D,$$

where  $D$  is a per-capita “demogrant” which adds equally into each consumer’s budget.

**Economic payoffs** The indirect utilities when firms maximize profits are:

$$V = V(T, t, q, Q) = M(T, t, \mu) + \frac{QY^{1-\sigma}}{1-\sigma} - (P + T)Y - \lambda(1 - \mu)Y \quad (6)$$

for a materialist and

$$v = v(T, t, q, Q) = M(T, t, \mu) + \frac{qy^{1-\sigma}}{1-\sigma} - (p + t)y - \lambda(1 - \mu)Y \quad (7)$$

for an environmentalist, where

$$M(T, t, \mu) = \varepsilon + \Pi(T) + \pi(t) + D - \omega[\mu n + (1 - \mu)N]. \quad (8)$$

Income per capita comprises  $\varepsilon$ , an exogenous endowment of numeraire goods, profits per capita from producing green and brown goods and the government demogrant, all less the cost of recruiting (training) scientists.

## 4 Dynamics

We now develop dynamics where the share of environmentalists and the qualities of both types of goods coevolve, as a result of households’ socialization decisions and firms’ innovation decisions. We also consider endogenous policy where two opportunistic parties compete for political power by setting the taxes on green and brown goods in a sequence of elections.

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<sup>8</sup>Although events such as the recent Gilet Jaunes demonstrations in France suggest that this conventional assumption may not be innocuous.

**Timing** Time is infinite, discrete, and indexed by  $s$ . The notion of a time period in our framework simultaneously captures several things: the electoral cycle, the innovation horizon, and the generational gap in socialization. While a more realistic model would treat these alternative horizons in a more nuanced way, we carry on with a “sequential-generation model” without further apology, as it buys a great deal of analytical simplicity.

When there is no risk of confusion, we use a short-hand notation for adjacent periods:  $z$  for  $z_s$  and  $z'$  for  $z_{s+1}$ . There are five stages to be studied within each period:

1. Society starts out with a stock of consumers/voters, and three state variables  $\{q, Q, \mu\}$  – i.e., initial quality levels and values (in the form of the environmentalist share).
2. Parties announce electoral platforms. Tax rates  $\{t, T\}$  are determined by the election outcome, which is subject to idiosyncratic and aggregate party shocks.
3. Current indirect utilities  $\{v, V\}$  are determined by firms’ outputs and prices and consumers’ demand.
4. Next-period’s qualities  $\{Q', q'\}$  are determined by firms’ innovation decisions.
5. Next-period’s share of environmentalists,  $\mu'$ , is determined by a replacement socialization process, which is subject to family-specific shocks.

Equilibrium outcomes at stage 3 was discussed in the previous section. We now embed this in the full model working in reverse order. First we study stages 4 and 5, taking the sequence of tax rates as given. We then close the model by exploring stage 2, where tax rates are determined in political equilibrium.

## 4.1 Socialization (stage 5)

The population turns over each period with the new generation of citizens being the driver of change.

These new agents are socialized once and for all, according to a “Darwinian” driver of values: the relative expected payoff from being one type

rather than another. For this to be viable, those involved in the socialization at  $s$  – physical parents, cultural parents, the young individual themselves – must be able to assess the (hypothetical) gain in well-being from adopting one identity rather than another. Specifically, denote the gain from becoming an environmentalist rather than a materialist by  $\Delta'$ . If  $\Delta' > 0$ , then the environmentalist share among the newly socialized,  $\mu'$ , increases relative to  $\mu$ , and more so the more environmentalists are expected to thrive.

The other driver in socialization is social mixing. For example, if parents have a single view about environmentalism or materialism, this is more likely inherited by their children. Similarly, if cultural parents are involved, non-homogenous matching – and hence social mixing – across families is important for the rate of change.

For concreteness, we base the rest of the analysis on a specific micro-founded sequential-generation model, where parents make consumption decisions and vote on behalf of their families before socializing their children at the end of period  $s$ .<sup>9</sup>

In this setting, as shown in the Appendix, the share of environmentalists evolves according to:

$$\mu' = \mu + \varkappa 2\mu(1 - \mu) \left[ F(\beta\Delta') - \frac{1}{2} \right]. \quad (9)$$

Here,  $F(\cdot)$  is the cumulative distribution function of a family-specific cultural-fitness shock, which is symmetric around a zero mean with density  $f(\cdot)$ . As a result,  $F(\cdot)$  increases smoothly in  $\Delta$  with  $F(0) = 1/2$ . On the right-hand side,  $\varkappa$  reflects the extent of social mixing, exposing individuals to different ideas from their parents. This parameter helps govern the speed of cultural dynamics with a higher  $\varkappa$  being associated with faster change.

But we can microfound a similar equation in other ways. Suppose the young in each generation are not just socialized by their own parents, but by other mentors in society as well. Then, social-mixing parameter  $\varkappa$  will also capture the rates at which different families meet across identities (see Besley and Persson 2019c for such an example in another context).

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<sup>9</sup>This kind of socialization model follows Bisin and Verdier (2001), Tabellini (2008), and Besley (2017).

## 4.2 Investments in Innovation (stage 4)

To study innovation, let  $\{\mathbf{t}, \mathbf{T}, \boldsymbol{\mu}\}$  denote future taxes and values from date  $s$  onwards. For the moment, we treat these as fixed. Firms choose investments in innovation to maximize the discounted sum of profits, using the same discount factor as consumers denoted by  $\beta$ .

We can write the value functions associated with this problem as

$$\begin{aligned}\tilde{\pi}(q, \mathbf{t}, \boldsymbol{\mu}) &= \arg \max_{n \geq 0} \{ \pi(q, t, \mu) - \omega n + \\ &\quad \beta \tilde{\pi} \left( q \left( 1 + \left( \frac{n}{q} \right)^\varphi \right), \mathbf{t}', \boldsymbol{\mu}' \right) \} \\ \tilde{\Pi}(Q, \mathbf{T}, \boldsymbol{\mu}) &= \arg \max_{N \geq 0} \{ \Pi(Q, T, \mu) (1 - \mu) - \omega N + \\ &\quad \beta \tilde{\pi} \left( Q \left( 1 + \left( \frac{N}{Q} \right)^\varphi \right), \mathbf{T}', \boldsymbol{\mu}' \right) \}.\end{aligned}$$

All firms can bid to employ scientists at wage  $\omega$  in a competitive market and do so to maximize their expected discounted profits, given (rationally) expected policies. The Euler equations associated with optimal innovation become

$$\left( \frac{N}{Q} \right)^{\varphi-1} \beta \varphi \sigma K(T') (1 - \mu') = \omega,$$

for the typical brown-variety firm and

$$\left( \frac{n}{q} \right)^{\varphi-1} \beta \varphi \sigma k(t') \mu' = \omega,$$

for the typical green-variety firm. Firms thus hire scientists up to the point where their marginal benefit in terms of future profits equals their marginal cost. A simplifying feature of the baseline model is that only  $\{t', T', \mu'\}$ , and no current variables, shape optimal investment decisions.<sup>10</sup> Moreover, each firm takes these expected future variables as given, since no individual firm is large enough to influence policy or culture on its own.

**Equilibrium structural change** Using (16), (17), we obtain the following expressions for the equilibrium growth rates for brown and green varieties

$$\tilde{g}(t', \mu') = \left( \frac{\beta \varphi \sigma k(t') \mu'}{\omega} \right)^{\frac{\varphi}{1-\varphi}} \quad (10)$$

$$\tilde{G}(T', \mu') = \left( \frac{\beta \varphi \sigma K(T') (1 - \mu')}{\omega} \right)^{\frac{\varphi}{1-\varphi}}. \quad (11)$$

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<sup>10</sup>This will no longer be the case in the extension with innovation subsidies in Section 5 below.

These expressions incorporate the effects on innovation incentives of the (expected) taxes, with each growth rate decreasing in its sectorial tax rate. Moreover, green (brown) growth is increasing (decreasing) in share of green consumers, due to a market-size effect.

In economic equilibrium, the qualities in the two sectors therefore evolve over time according to

$$\begin{aligned}\tilde{Q}(\mu', T', Q) &= Q(1 + \tilde{G}(T', \mu')) \\ \tilde{q}(\mu', t', q) &= q(1 + \tilde{g}(t', \mu')).\end{aligned}$$

### 4.3 Politics and Taxes (stage 2)

We know from Acemoglu et al (2012), and subsequent work along the same lines, that brown-goods taxation may change the trajectory of economies with endogenous technological change. However, that research only considers exogenous taxes, rather than policies implemented in political equilibrium. In this section, we explore the politics of environmental taxes in a simple model of elections. Section 5 enriches this model to encompass a wider range of political influences.

As in Besley and Persson (2019a), our baseline model studies electoral environmental politics as two-party competition with probabilistic voting (Lindbeck and Weibull 1987, Persson and Tabellini 2000). We label the two (given) parties  $P = A, B$  and assume these are solely motivated by winning elections. Each party chooses a proposed tax platform:  $\{T^A, t^A\}$  and  $\{T^B, t^B\}$ . We pick this particular formulation for pure convenience. As discussed in Besley and Persson (2019a), other political models would yield similar conclusions.

**Voters** Voters are of two kinds. Swing voters cast their ballots based on proposed policy platforms and loyal voters cast their ballots for one party. This distinction follows a long-standing, political-science tradition based on the Michigan voting surveys. To simplify the algebra, the baseline model assumes the same proportion of swing voters among materialists and environmentalists (this is relaxed in Section 5.1).

**Expected voter utility** Now consider a particular voter and parent of identity type  $\tau \in \{e, m\}$  when parties make their policy proposals at stage

2. Her expected utility, including the discounted payoff of her offspring, can be written as

$$W(\tau) = I[e]v(t, T, q, Q) + (1 - I[e])V(t, T, q, Q) + \beta E\{I[e]v(t', T', q(1 + \tilde{g}(t', \mu'))) + (1 - I[e])V(t', T', Q(1 + \tilde{G}(t', \mu')))\}, \quad (12)$$

where  $I[\tau] = 1$  if and only  $\tau = e$ .<sup>11</sup> The expectation  $E$  on the second line reflects uncertainty – for parents in mixed-identity marriages – about the family shock, which will be realized at stage 5 of the model.

As voters are forward-looking, they would prefer parties to raise their children’s payoff. However, parties cannot deliver on this preference. They are certainly large enough to internalize the aggregate effects of their actions, but in the baseline model they have no way of affecting  $\{\mu', t', T'\}$ , the determinants of the future payoff on the second line of (12). First, politicians lack commitment to directly change future policies. Second, current taxes  $\{t, T\}$ , which they do control, cannot be leveraged to alter  $\{\mu', t', T'\}$  in an indirect way. Thus, politicians – as do individual firms and households – must take future variables  $\{\mu', t', T'\}$  as given. Their best strategy is then to garner votes from the swing voters by strategically setting  $\{t, T\}$  in a way that promotes the voters’ current payoff on the first line of (12).

**Shocks to swing-voter utility** Following the probabilistic-voting approach, the party choice by swing voters is also subject to idiosyncratic shocks, among individual voters, and aggregate shocks, common to all voters. A materialist swing voter supports party  $A$  if

$$V(t^A, T^A, q, Q) + \eta + \zeta \geq V(t^B, T^B, q, Q),$$

where  $\eta$  is the idiosyncratic shock and  $\zeta$  the aggregate shock. Both shocks are assumed to be uniformly distributed:  $\eta$  on  $[-1/E, 1/E]$  and  $\zeta$  on  $[-1/X, 1/X]$ . This simple formulation – and our specific assumptions about individual utilities – gives a simple solution for policy.

Integrating over  $\eta$ , we can now find the share of materialist swing voters who vote for party  $A$ :

$$\frac{1}{2} + E [V(t^A, T^A, q, Q) - V(t^B, T^B, q, Q) + \zeta]. \quad (13)$$

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<sup>11</sup>Note that parents consider the payoffs to their children under the alternative identities as materialists and environmentalists.

We assume an interior solution – i.e., (13) lies strictly in the unit interval. A parallel expression holds for environmentalist swing voters.

**Winning probabilities** Party  $A$  wins the election if it gets more than half of the votes. This will happen if

$$\zeta + \Gamma(t^A, T^A, t^B, T^B, \mu) \geq 0, \quad (14)$$

where

$$\Gamma(t^A, T^A, t^B, T^B, \mu) = \frac{\mu [v(t^A, T^A, q, Q) - v(t^B, T^B, q, Q)]}{(1 - \mu) [V(t^A, T^A, q, Q) - V(t^B, T^B, q, Q)]}.$$

The first term in (14) is positive if the realized aggregate shock  $\zeta$  favors party  $A$ , while the second is positive if the party's policy platform allows it to court swing voters.

Integrating over  $\zeta$  (and exploiting the uniform density), gives us the following probability that party  $A$  wins the election:

$$z^A = \frac{1}{2} + X\Gamma(t^A, T^A, t^B, T^B, \mu), \quad (15)$$

assuming an interior solution.<sup>12</sup> Party  $B$  wins with the complementary probability  $z^B = 1 - z^A = \frac{1}{2} - X\Gamma(t^A, T^A, t^B, T^B, \mu)$ . Each party's probability of winning is thus given by the same function. Given the expression for  $\Gamma(t^A, T^A, t^B, T^B, \mu)$ , this common objective function is concave. Moreover, it is “as if” each party is maximizing a Utilitarian social-welfare function. This is a useful benchmark, as the political equilibrium maximizes static welfare, as do classic Pigouvian taxes.

**Equilibrium tax rates** To study equilibrium policy choices, we look for a Nash equilibrium where each party optimizes its policy platform, given the platform of the other. This gives us the following useful result (see the Appendix for the proof of this and all subsequent propositions).

**Proposition 1** *In political equilibrium, both parties choose the same tax rates:*

$$\hat{T} = (1 - \sigma)\lambda - \sigma\chi \quad \text{and} \quad \hat{t} = -\sigma\chi.$$

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<sup>12</sup>This will always be the case if  $X$  is small enough – i.e., there is a wide enough support for aggregate shock  $\zeta$ .

Taxes have to do two things. One is to offset the monopoly distortion from mark-up pricing due to imperfect competition. As a result, the green tax rate is negative and can be thought about as a subsidy. The other role of taxation is to correct, in a Pigouvian fashion, for the damage from brown-sector pollution, which materialist consumers do not internalize. To see this, note that  $\chi + \lambda$  is the brown-sector social marginal output cost, while  $\chi$  is the green-sector social marginal cost. Whenever these costs are constant over time, as we assume here, so are equilibrium tax rates.

**Implications** Equilibrium taxation affects the profits in each sector. In particular, the equilibrium value of variable  $k(t)$  that enters (5) becomes

$$k(\hat{t}) = [(\chi + \hat{t}) / (1 - \sigma)]^{1 - \frac{1}{\sigma}} = \chi^{1 - \frac{1}{\sigma}} > [\chi / (1 - \sigma)]^{1 - \frac{1}{\sigma}}. \quad (16)$$

Compared to a situation of no taxation, profits of green-sector firms are higher due to the subsidy on such goods.

Similarly, we can write variable  $K(T)$  that enters (4) as

$$K(\hat{T}) = [(\chi + \hat{T}) / (1 - \sigma)]^{1 - \frac{1}{\sigma}} = [\chi + \lambda]^{1 - \frac{1}{\sigma}} < [\chi / (1 - \sigma)]^{1 - \frac{1}{\sigma}}. \quad (17)$$

Compared to no taxation, taxation at  $\hat{T} > \hat{t}$  lowers profits for brown-variety firms. Equilibrium policy thus encourages green consumption and raises the profitability of green goods, but reduces consumption and profitability of brown goods.

#### 4.4 Full Dynamic Equilibrium

We now put together the economic, social, and political dynamics to explore the path taken by the economy.

**Payoffs and growth rates with optimal taxes** Combining the result in Proposition 1 with indirect utilities (6) and (7), we obtain

$$U(q, Q) = \frac{\sigma}{1 - \sigma} Q^{\frac{1}{\sigma}} [\chi + \lambda]^{1 - \frac{1}{\sigma}} - \lambda Q^{\frac{1}{\sigma}} [\chi + \lambda]^{-\frac{1}{\sigma}} \quad (18)$$

$$\text{and } u(q, Q) = \frac{\sigma}{1 - \sigma} q^{\frac{1}{\sigma}} \chi^{1 - \frac{1}{\sigma}} - \lambda Q^{\frac{1}{\sigma}} [\chi + \lambda]^{-\frac{1}{\sigma}}, \quad (19)$$

as the welfare levels for materialists and environmentalists at equilibrium policy. The first term reflects the quality of consumption goods, whereas the second reflects the negative externality from brown-goods consumption.

With politically optimal taxes, the growth rates are

$$\begin{aligned} G(\mu', \lambda) &= \left( \frac{\beta \varphi \sigma (\chi + \lambda)^{1-\frac{1}{\sigma}} (1 - \mu')}{\omega} \right)^{\frac{\varphi}{1-\varphi}} \\ g(\mu') &= \left( \frac{\beta \varphi \sigma (\chi)^{1-\frac{1}{\sigma}} \mu'}{\omega} \right)^{\frac{\varphi}{1-\varphi}}, \end{aligned}$$

implying that equilibrium qualities develop over time as

$$\hat{Q}(\mu', \lambda, Q) = Q [1 + G(\mu', \lambda)], \quad \hat{q}(\mu', q) = q [1 + g(\mu')]. \quad (20)$$

Since  $\hat{Q}(\mu', \lambda, Q)$  and  $\hat{q}(\mu', q)$  are monotonic in  $\mu$ , the dynamic equilibrium will be recursive in  $\mu$ .

**Value dynamics** If the parameters satisfy (see the Appendix):

$$1 - 2\mu(1 - \mu)(1 - \nu)\beta f(\beta \Delta(\mu, q, Q)) \Delta_{\mu}(\mu, q, Q) > 0 \text{ for all } \mu \in [\underline{\mu}, \bar{\mu}], \quad (21)$$

then the value dynamics are well-behaved with convergence to a steady state. From (22), we know that  $\Delta_{\mu} > 0$ , reflecting a dynamic complementarity between values and technology based on the market-size effect. Specifically, as the share of environmentalists rises, this boosts green-sector profits which spurs innovation and quality in that sector. The complementarity is analogous to those that arise in the study of platform technologies.

Using (18), (19), and (20), we obtain the following expression for the equilibrium cultural fitness of environmentalism

$$\begin{aligned} \Delta' &= \Delta(\mu', q, Q) = u\left(\hat{Q}(\mu', \lambda, Q), \hat{q}(\mu', q)\right) - U\left(\hat{Q}(\mu', \lambda, Q), \hat{q}(\mu', q)\right) \\ &= \frac{\sigma}{1 - \sigma} \left[ \hat{q}(\mu', q)^{\frac{1}{\sigma}} \chi^{1-\frac{1}{\sigma}} - \hat{Q}(\mu', \lambda, Q)^{\frac{1}{\sigma}} [\chi + \lambda]^{1-\frac{1}{\sigma}} \right]. \end{aligned} \quad (22)$$

Putting this expression into (9), the equilibrium dynamics of the model become effectively one-dimensional. Combining (9) and (22), we can fully characterize these dynamics by

$$\text{sgn } \Delta' = \text{sgn } \delta(\mu', q/Q, \lambda),$$

where function  $\delta$  is defined by

$$\delta(\mu', q/Q, \lambda) = \frac{q}{Q} \cdot \frac{1 + g(\mu')}{1 + G(\mu', \lambda)} - \left[ \frac{\chi}{\chi + \lambda} \right]^{1-\sigma}. \quad (23)$$

The expected fitness of being an environmentalist rather than a materialist thus depends (i) positively on the current ratio of green-to-brown-goods quality, (ii) positively on the extent of environmentalism, via the relative green-to-brown growth rate, and (iii) negatively on the ratio of the (social) marginal costs of green goods and brown goods. The dynamics are fully characterized by the sign of  $\delta(\mu', q/Q, \lambda)$ , which determines the sign of  $\Delta'$ . That, in turn, determines whether the share of people with green lifestyles – and the quality of green relative to brown goods – is growing or shrinking.

**Steady states** Under the mild assumption that  $G(\underline{\mu}, \lambda) \geq g(\underline{\mu})$  (see the Appendix), the equilibrium dynamics are divergent. They can be summarized as follows:

**Proposition 2** *Given  $(\mu, q/Q)$  and parameter  $\lambda$  – and condition (21) – values converge to an environmentalist steady state where  $\mu = \bar{\mu}$  if  $\delta(\mu, q/Q, \lambda) > 0$  and to a materialist steady state where  $\mu = \underline{\mu}$  if  $\delta(\mu, q/Q, \lambda) < 0$ .*

These divergent dynamics reflect the aforementioned complementarities. Technical change becomes more and more directed towards whichever group of consumers that grows: environmentalists or materialists. This makes it more attractive to identify with the growing group. And so on.

Proposition 2 also says that we only need to know the initial values of  $\mu$ ,  $q$  and  $Q$ , plus damage parameter  $\lambda$ , to know whether a society will converge to an environmentalist or materialist steady state. As is clear from the proof of Proposition 2 (see the Appendix), the sign of  $\delta(\mu, q/Q, \lambda)$  implies the sign of  $\delta(\mu', q/Q, \lambda)$  defined in (23). Moreover, if  $\delta(\mu, q/Q, \lambda) < 0$ , then society converges to the maximally materialist steady state with declining environmental values and faster quality improvements for brown than for green goods.

The model's dynamics are illustrated in Figure 1, which has three panels. In panel A,  $\delta(\mu, q/Q, \lambda) > 0$  for all  $\mu$  and society converges to  $\bar{\mu}$  regardless of the starting value, while panel B portrays the opposite case where

$\delta(\mu, q/Q, \lambda) < 0$  with convergence to  $\underline{\mu}$ . However, in panel C, there is an interior critical value of  $\mu$  such that  $\delta(\mu, q/Q, \lambda) = 0$ . Which steady state society converges to now depends on whether  $\mu$  starts above or below this critical value. We find the last possibility the most interesting one.

**Welfare comparisons** We have talked about a “brown” steady state – with maximally materialist values – as a “climate trap.” This label begs the question whether this steady state has lower welfare than a “green”, maximally environmentalist, steady state.<sup>13</sup> As intuition suggests, a sufficient condition for an affirmative answer is that pollution damages captured by parameter  $\lambda$  are large enough.

To make this point requires an explicit welfare criterion. This is not entirely straightforward in our model, where not only the technology but also the composition of values (and hence of preferences) in the population differs across the two steady states. However, our utilitarian welfare evaluation rests on precisely the same hypothetical comparison as the one the agents make in our model of cultural evolution.

We compare welfare in the two steady states with  $\mu = \bar{\mu}$  or  $\mu = \underline{\mu}$ , evaluated by the values held in those steady states. To do so, we write period- $s$  utilitarian welfare as a weighted average of the equilibrium indirect utility of materialists and environmentalists in (18) and (19). This yields

$$\begin{aligned} & \frac{\sigma}{1-\sigma} \mu_s \Delta(\mu_s, q_s, Q_s) + \frac{\sigma}{1-\sigma} Q_s^{\frac{1}{\sigma}} [\chi + \lambda]^{1-\frac{1}{\sigma}} - \lambda Q_s^{\frac{1}{\sigma}} [\chi + \lambda]^{-\frac{1}{\sigma}} \\ = & \frac{\sigma}{1-\sigma} \mu_s \Delta(\mu_s, q_s, Q_s) + Q_s^{\frac{1}{\sigma}} \varphi(\lambda), \end{aligned} \quad (24)$$

where  $\Delta(\mu_s, q_s, Q_s)$  is the same welfare difference that appears in (9), our expression for the evolution of environmental values  $\mu$ . In the second-line expression

$$\varphi(\lambda) = \frac{\sigma}{1-\sigma} [\chi + \lambda]^{1-\frac{1}{\sigma}} - \lambda [\chi + \lambda]^{-\frac{1}{\sigma}}$$

is a decreasing function of  $\lambda$  with  $\varphi(0) > 0$  and  $\varphi_\lambda(\lambda) < 0$  for  $\sigma < 1/2$ . Moreover  $\lim_{\lambda \rightarrow \infty} \inf \varphi(\lambda) \leq 0$ .

Now, consider a green steady state at  $\bar{\mu}$  with (quality) growth rates  $\bar{g}, \underline{G}$ .

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<sup>13</sup>We do not consider the harder problem of comparing the entire dynamic paths, including the transitions to these steady states.

By (24), we can write welfare in that steady state as

$$\sum_{s=0}^{\infty} \beta^s \left[ \frac{\sigma}{1-\sigma} \bar{\mu} \Delta(\bar{\mu}, q_s, Q_s) + Q_s^{\frac{1}{\sigma}} \varphi(\lambda) \right].$$

Similarly, welfare in a brown steady state at  $\underline{\mu}$ , with growth rates  $\bar{G} > \underline{G}$ , and  $\underline{g} < \bar{g}$ , is

$$\sum_{s=0}^{\infty} \beta^s \left[ \frac{\sigma}{1-\sigma} \underline{\mu} \Delta(\underline{\mu}, q_s, Q_s) + Q_s^{\frac{1}{\sigma}} \varphi(\lambda) \right].$$

We know that  $\Delta(\bar{\mu}, q_s, Q_s) > 0 > \Delta(\underline{\mu}, q_s, Q_s)$  for all  $s$ , as the steady states are stable. A sufficient condition for a positive welfare difference is thus that

$$\varphi(\lambda) \left[ \sum_{s=0}^{\infty} \beta^s \left[ [Q_0^G (1 + \underline{G})^s]^{\frac{1}{\sigma}} - [Q_0^B (1 + \bar{G})^s]^{\frac{1}{\sigma}} \right] \right] > 0$$

for any pair of initial brown-good qualities  $\{Q_0^G, Q_0^B\}$ . This condition is fulfilled for large enough  $\lambda$ , because  $\lim_{\lambda \rightarrow \infty} \inf \varphi(\lambda) \leq 0$  and the expression under the summation sign is negative (as  $\bar{G} > \underline{G}$ ). Independently of initial brown good qualities, welfare will thus be higher in the green steady state, if emission costs  $\lambda$  are large enough.

**Implications** We end this section by discussing some implications of Proposition 2 and our underlying model. We also discuss how parameter shifts can alter society's dynamic path.

In terms of the production side of the economy, the model predicts a changing pattern on the equilibrium path along with a changing  $\mu$ . Where environmental values are growing, quality growth more and more favors green goods consumption. Even if initially  $q/Q < 1$ , green product quality will catch up with – and eventually overtake – brown product quality. This means that the physical consumption of green goods is increasing faster than that of brown goods. In the end, the economy will converge to a maximal growth rate of green-goods quality  $g(\bar{\mu})$  and a minimal growth rate of brown-goods quality  $G(\bar{\mu}, \lambda)$ .

The time path of pollution in the model is given by  $\lambda(1 - \mu)Y$ . This need not be monotonic over time, as  $Y$  can rise (by brown-goods technological change encouraging consumption) even though  $\mu$  is rising. In the steady state of our baseline model, pollution continues to grow even in the green steady

state as long as  $\bar{\mu} < 1$  – i.e., not all consumers become environmentalists. However, we could easily add other features that could make brown goods decline or disappear. For example, competition for scarce production factors between green- and brown-goods producers would eventually make brown goods unprofitable or inviable and make emissions go to zero.

**Comparative dynamics** Proposition 2 shows how values (culture) may sustain a climate trap and bring about path dependence. To see this, consider two societies with identical economic opportunities and technologies. These might diverge just because starting values are different, say,  $\mu^H > \mu^L$  such that  $\delta(\mu^H, \frac{q}{Q}, \lambda) > 0 > \delta(\mu^L, \frac{q}{Q}, \lambda)$ . Under this condition, green values and technology would decline from  $\mu^L$ , but rise from  $\mu^H$ . Initial values alone can thus make a crucial difference, with one society becoming greener and cleaner, and another – with identical economic fundamentals – becoming browner and dirtier. Maybe an initial shock to environmentalism – e.g., following a natural disaster – could have a similar effect.

Now consider the impact of two “MIT-shocks” (i.e., unanticipated permanent shocks at some time period  $s$ ). The first is a hypothetical shift from  $\lambda^L$  to  $\lambda^H > \lambda^L$ . This could be due to science or salience. As for science, this might reflect increased warnings by climate scientists about the destructive effects of carbon emissions. As for salience, the shift might reflect a group of concerned, who manage to persuade their fellow citizens – through social media, physical demonstrations, or other channels – that the problem of climate change is worse than they previously thought. This is one way to think about the logic of “declaring a climate emergency.”

Our framework predicts that politics would respond to such a shift by a higher tax on brown goods. This, in turn, would reorient technological change from brown to green technologies. If the shift is large enough, or society close enough to the critical juncture where  $\delta(\mu, \frac{q}{Q}, \lambda) = 0$ , it could be that  $\delta(\mu, \frac{q}{Q}, \lambda^H) > 0 > \delta(\mu, \frac{q}{Q}, \lambda^L)$ . This could put the economy on a different dynamic path, where values now evolve to escape the climate trap.

The second MIT-shock is a pro-green technology shift, raising  $q$  from  $q^L$  to  $q^H$ . This could be due to opening up imports of new green technologies developed in other countries (think e.g., cheap solar cells from China). By making it cheaper to identify as an environmentalist, this might shift the economy out of a climate trap if  $\delta(\mu, \frac{q^H}{Q}, \lambda) > 0 > \delta(\mu, \frac{q^L}{Q}, \lambda)$ .

We summarize these observations as

**Proposition 3** *Large enough positive exogenous shocks to parameter  $\lambda$  or variables  $q$  and  $\mu$  can make society escape a climate trap and converge to  $\bar{\mu}$  rather than  $\underline{\mu}$ .*

In all cases, the complementarities in our model make the new trajectory sustainable via mutually reinforcing technology, politics and values. The shocks do not have to be permanent, as long as values develop far enough that the condition  $\delta(\mu, \frac{q}{Q}, \lambda) > 0$  holds, once the shift subsides. Another way to say this is that the model can exhibit path dependence: temporary shocks can have permanent effects.

## 5 Enriching the Model

Our baseline model above makes restrictive assumptions about the actions available to households, firms, and political parties. We now enrich these aspects of the model.

A key part is expanding the nature of political influence. First, we allow environmentalists to influence outcomes beyond their effect on consumer demand. Following Besley and Persson (2019a) and (2019b), we allow the salience of environmental policy to be stronger for this group, enhancing their influence as swing voters. We then allow environmentalism to affect the behavior of scientists, or alternatively direct political-influence activity, often referred to as “private politics” (Baron 2003). Finally, we consider political activity by firms in the form of lobbying. By considering these, we gain new insights into how political factors can perpetuate or end a climate trap.

We then enrich the policy space by introducing a subsidy to green innovation, such that politicians can affect the welfare levels of the offspring of current voters. This can lead to strategic influence which speeds the transition towards ending a climate trap, although the role played by politics in shaping this remains central.

### 5.1 Environmental Salience

Part and parcel of being an environmentalist is to consider reduced pollution a salient policy issue. We now extend our baseline model so that environmentalists have a higher weight on pollution in their preference function. This is realistic if environmentalism responds to media coverage and to increasing

climate awareness. In standard models, this would influence policy outcomes by changing political priorities. In our model, such responses have dynamic implications by giving additional impetus to the (political) feedback mechanism as environmentalists become more likely to act as swing voters. This makes a climate trap less likely.

**Differential salience across types** To capture different concerns for pollution, suppose – as in Besley and Persson (2019a) – the utility function of environmentalists is

$$x + \int_0^1 \frac{qy^{1-\sigma}}{1-\sigma} di - (\lambda + \theta) \int_0^1 \bar{Y}(j) dj.$$

The additional weight  $\theta$  on pollution damages makes this outcome more salient. As we discuss, and formally analyze in Besley and Persson (2019b), higher salience in an identity group (like environmentalists) can also reflect a stronger – collective rather than individual – identity, due to a social movement in which the members participate.

With this change, we may go through the same steps as in Sections 3 and 4. Doing so, modifies Proposition 1 to

**Proposition 1'** *In political equilibrium with additional salience by environmentalists of  $\theta$  and fraction of environmentalists,  $\mu$ , both parties choose the same tax rates:*

$$\hat{T} = (1 - \sigma)(\lambda + \mu\theta) - \sigma\chi \quad \text{and} \quad \hat{t} = -\sigma\chi.$$

The corrective tax on brown goods now reflects a weighted group average of the damages from pollution. Crucially it depends on  $\mu_s$  when  $\theta > 0$ . As a result, the brown-goods tax is no longer constant over time but rises (falls) as more (less) people tilt towards environmentalism. This enhances the complementarity driving our dynamics; with more environmentalists around, brown-goods taxes are expected to rise, which makes it even more attractive to become an environmentalist.

Formally, Proposition 2 still governs the dynamics, but we have to change the functional form to

$$\delta(\mu, q/Q, \lambda) = \frac{q}{Q} \cdot \frac{1 + g(\mu)}{1 + G(\mu, \lambda + \mu\theta)} - \left[ \frac{\chi}{\chi + (\lambda + \mu\theta)} \right]^{1-\sigma}.$$

Earlier, the positive effect of a higher  $\mu$  on  $\delta$  – and hence on the sign of  $\Delta$  – only reflected an “economic complementarity” via the green vs. brown growth rate  $g(\mu)/G(\mu, \lambda)$ . But now it gets reinforced by a “political complementarity” via the brown tax rate. As a result, society is less likely to end up in a climate trap.

**A different composition of swing voters** A stronger engagement for greener policies among environmentalists may show up in politics, if more environmentalists are willing to switch their vote based on the party platforms in the electoral campaign. Our baseline model abstracts from this, as environmentalists and materialists have the same share of swing voters.

Assume instead, following Besley and Persson (2019a, Online Appendix) that of environmentalists, a share  $\epsilon > 1/2$  are swing voters, while only a share  $(1 - \epsilon)$  of materialists are swing voters. Then, the function  $\Omega(T^A, t^A, T^B, t^B, \mu)$  maximized by politicians no longer has pure population weights, as it becomes biased towards swing voters. Instead, we have

$$\Gamma(t^A, T^A, t^B, T^B, \mu) = \frac{\epsilon\mu [v(t^A, T^A, q, Q) - v(t^B, T^B, q, Q)]}{(1 - \epsilon)(1 - \mu) [V(t^A, T^A, q, Q) - V(t^B, T^B, q, Q)]},$$

such that environmentalists get a higher (lower) weight than their true population share when  $\epsilon$  is above (below) one half. In this extension, the common brown-goods tax rate becomes  $\hat{T} = (1 - \sigma)(\lambda + 2\epsilon\mu\theta) - \sigma\chi$ . When environmentalists dominate among swing voters, policy thus responds even more strongly to the environmentalist share than in the previous extension.

Formally, Proposition 2 still governs the dynamics, but we have to change the functional form to

$$\delta(\mu, q/Q, \lambda) = \frac{q}{Q} \cdot \frac{1 + g(\mu)}{1 + G(\mu, \lambda + 2\epsilon\mu\theta)} - \left[ \frac{\chi}{\chi + (\lambda + 2\epsilon\mu\theta)} \right]^{1-\sigma}.$$

The upshot is similar to that with an increased weight on pollution, except that the political complementarity is now stronger and more so the larger is the  $\epsilon - 1/2$  wedge.

**Implications** Growing rhetoric among environmentalists can persuade them to vote more for parties which offer stringent environmental policies. Even as a minority, environmentalists can get disproportionate attention and push up taxes on brown goods, which can help break the climate trap. Of course,

things can go the other way if materialists get upset – as we saw when the Gilets Jaunes made President Macron back off from his proposed hike of gasoline taxes. Our model draws attention to the long-run implications of such phenomena and shows how the intensity of preferences can shape the dynamics.

## 5.2 Motivated Citizens

We now allow environmentalist citizens to act on their identity not only as consumers, but also as scientists/inventors, or as activists in private politics. Both these margins of action change the investment or production costs for green or brown firms, respectively. This channel does not reflect that environmentalists have a greater intensity of preferences, but that their actions in alternative domains impinge on the interplay between technological and value change.

**Motivated scientists** Scientists form an important part of civil society. Organizations like the National Academy of Sciences, The Royal Society, or the Royal Swedish Academy of Sciences represent and project their views and values, sometimes clashing with political authority. As an example, scientists such as Rachel Carson were the first to alert the world to ugly pollution and climate dynamics.

Here, we emphasize that the collective action of scientists can work via market incentives by changing the supply price of innovation to different sectors: scientists who care about pollution may be more attracted to green sectors.<sup>14</sup> We model this by letting scientists act as “motivated agents” in the language of Besley and Ghatak (2005). Specifically, we suppose that the share of inventors with environmental values coincides with  $\mu$ , the share in the population at large. Moreover, environmentalist inventors are willing to accept a lower wage  $(1 - \gamma)\omega$  – with compensating differential  $\gamma < 1$  – if they get to work on green-sector, rather than brown-sector, innovations.

Firms in the two sectors now offer different training contracts for scientists: the green sector is able to offer  $w = (1 - \gamma)\omega$ , while the brown-sector wage is  $W = \omega$ . This cost advantage to the green sector will show up in the

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<sup>14</sup><https://www.bloomberg.com/news/articles/2019-08-01/the-oil-industry-s-talent-pipeline-slows-to-a-trickle> reports that fossil fuel companies are now having increasing difficulties in attracting new graduates.

number of scientists hired. While the brown growth rate is the same as in the baseline model, the green growth rate becomes  $g(\mu/(1-\gamma)) > g(\mu)$ .

**Implications of motivated inventors** The fitness of environmentalism is now given by

$$\delta(\mu, q/Q, \lambda, \gamma) = \frac{q}{Q} \cdot \frac{1 + g(\mu/(1-\gamma))}{1 + G(\mu, \lambda)} - \left[ \frac{\chi}{\chi + \lambda} \right]^{1-\sigma},$$

a higher value than in the baseline model. All else equal, we are thus less likely to be in a climate trap. As before, close to a critical juncture, a boost to green growth may push society across this threshold. It follows that scientists exercise political power, but only indirectly through the market system without any political collective action. However, if we imagined scientists creating a collective identity as environmentalists, such salience could be a way of increasing  $\gamma$ .

This extension emphasizes how market-based mechanisms can help avoid a climate trap. This effect of environmentalism occurs on the supply side of firms and reinforces the market-size effect on the demand side.

**Private politics** Environmentalists frequently engage in private politics (Baron 2003, Abito et al 2019). CEOs of resource companies fear the actions of movements like the Rainforest Action Network who operate outside the standard political process, pressuring brown-goods firms to mitigate their environmental impact.<sup>15</sup> This can involve a range of activities such as sit-ins, public boycotts of certain goods, or publicity campaigns, whereby environmentalists threaten brown firms to lower their emissions.<sup>16</sup> Such threats raise the cost of doing business when they drive brown firms to invest in additional security measures or PR-activities to offset the negative reputational consequences of activists.

This suggests a very simple model: activists raise the cost of doing business by pushing up the marginal cost of all brown firms by  $\mu\lambda d$ , where  $d > 0$  denotes the expected damages imposed per firm. We take such activity as exogenous (but could easily endogenize the incentives to engage in protest). Current protest costs cut current profits and production, and

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<sup>15</sup>See <https://www.ran.org/>.

<sup>16</sup>Bezin (2015) proposes a model of cultural evolution for environmental preferences based on private contributions to environmental protection.

expected protest costs affect investments in innovation via future expected profits.

The equilibrium tax rates are set as in Section 3 and now become

$$\hat{T} = (1 - \sigma) \lambda - \sigma (\chi + \mu \lambda d).$$

This means a *lower* brown-goods tax – before it was  $\hat{T} = (1 - \sigma) \lambda - \sigma \chi$  – due to the higher marginal cost of production. In other words, optimal policy undoes a portion of the higher marginal cost to prevent it from being passed on to consumers. However, in the end, the *after-tax* brown-goods marginal production cost goes up to  $(1 - \sigma)(\chi + \lambda(1 + \mu d)) > (1 - \sigma)(\chi + \lambda)$ .

**Implications of private politics** Private politics has both direct and indirect effects on the dynamics of technology and values. The direct effects reflect the fact that producing brown goods is now more expensive and the incentives to innovate therefore lower. The indirect effect comes from the value dynamics, which are now governed by

$$\delta(\mu, q/Q, \lambda(1 + \mu d)) = \frac{q}{Q} \frac{1 + g(\mu)}{1 + G(\mu, \lambda(1 + \mu d))} - \left[ \frac{\chi}{\chi + \lambda(1 + \mu d)} \right]^{\frac{1}{1-\sigma}}.$$

Along a path where  $\mu$  is rising (falling), it is thus as if the marginal damage cost is increasing (decreasing) over time. More (less) environmentalists means more (less) direct pressure on brown firms. This magnifies the feedback effects we have already studied. But the qualitative picture is unchanged, meaning that the sign of  $\delta(\mu, q/Q, \lambda(1 + \mu d))$  fully characterizes the dynamic path.

This is true even though we have not allowed activism to directly enter the payoffs of environmentalists. If activism is “warm-glow,” or negative-reciprocity, it will further boost payoffs of environmentalists and hence further raise  $\delta(\mu, q/Q, \lambda(1 + \mu d))$ . If activism is costly, however, the fitness of environmentalism still rises, as long as the pressure costs do not outweigh the lower quality and higher costs of brown goods.

Actions of climate activists are often dismissed as social signalling. But our analysis shows that such actions can have static and dynamic effects beyond any impact on policy. Whether these effects make a society more likely to avoid a climate trap depends on the scale of actions and their effects on brown-firm costs.

### 5.3 Lobbying by Firms

Firms lobby government in a range of domains, and climate politics is no exception. A vast literature points to the static distortions of lobbying, favoring organized firms at the expense of consumers. But in our framework, lobbying can have dynamic implications as well. To explore this possibility, we extend the baseline model with more traditional influence activities, where firms in both sectors can pay campaign contributions to political parties with policies favorable to their profits. We follow the approach of Baron (1994), where opportunistic parties choose policy platforms partly to please prospective contributors who can help them win elections. This captures the intuitive policy biases that arise if one group of firms (green or brown) is more organized than another.

**Basics** As before, we study sector-wide taxes  $\{t, T\}$  rather than taxes on individual varieties. A closed interval  $[0, \phi]$  of green-sector firms participate in a coalition that interacts with political parties. Specifically, each participating firm agrees on paying a campaign contribution  $c^P$  to party  $P$  at cost  $\frac{1}{2}(c^P)^2$ . In the same way, an interval  $[0, \Phi]$  of brown-sector firms make contributions  $C^P$  at cost  $\frac{1}{2}(C^P)^2$ . These contributions are decided upon after parties have designed their policy platforms, but before the election.

The total contributions collected by each party are thus

$$\int_0^\phi c^P di + \int_0^\Phi C^P dj = \phi c^P + \Phi C^P.$$

These monies allow parties to monotonically raise their probability of winning elections. To simplify, we use a reduced-form parametric formulation (see Persson and Tabellini 2000, ch. 7), where total campaign contributions of the two parties modify (15), the probability of winning, as

$$z^A = \frac{1}{2} + X \{ \Gamma (T^A, t^A, T^B, t^B, \mu) + \sqrt{\xi} [\phi c^A + \Phi C^A - (\phi c^B + \Phi C^B)] \}. \quad (25)$$

Parameter  $\xi > 0$  measures how effectively money influences electoral outcomes.

**Equilibrium policy** In an intermediate step, we derive the optimal contributions of each firm. In another, we derive the common maximand of the

two political parties, which augments the earlier Utilitarian objective by a weighted average of profits in the two sectors. After these steps (see the Appendix), we can state the main result in this subsection

**Proposition 4** *In political equilibrium, with lobbying by organized firms, both parties choose the same tax rates*

$$\hat{T} = \frac{(1 - \sigma)\lambda - \sigma\chi(1 + \Phi\xi(1 - \sigma))}{1 + \Phi\xi(1 - \sigma)\sigma} \text{ and } \hat{t} = -\sigma\chi \frac{(1 + \xi\phi(1 - \sigma))}{(1 + \xi\phi(1 - \sigma)\sigma)}.$$

The two expressions neatly summarize the distortions that lobbying brings about. To see this, note that the result is the same as in Proposition 1, when either  $\xi = 0$  – money is ineffective in politics – or  $\Phi = \phi = 0$  – no firms are organized to lobby. As  $\xi$  increases, the subsidy on green goods rises and the tax on brown goods falls. However, this strikes differently across green and brown sectors if  $\Phi$  and  $\phi$  differ – i.e., lobbying organization is asymmetric. If brown firms are more established and organized ( $\Phi > \phi$ ), then this lowers  $T$  relative to  $t$ .

**Implications** To see the impact of lobbying, note that the ratio of social marginal costs  $\chi/(\chi + \lambda)$  in the equilibrium policies gets adjusted to

$$\frac{1 + \Phi\xi(1 - \sigma)\sigma}{1 + \phi\xi(1 - \sigma)\sigma} \cdot \frac{\chi}{\chi + \lambda}.$$

This adjusted marginal-cost ratio reveals that a larger coalition  $\Phi$  makes policy more advantageous to brown firms and thus encourages their output and innovation. On the contrary, a higher  $\phi$  encourages greater green-firm output and innovation. If  $\Phi > \phi$ , then the condition for escaping the climate trap,  $\delta(\mu, q/Q, \lambda) > 0$ , is *less* likely to hold. Hence, endogenously chosen lobbying by brown-sector firms raises the likelihood of a climate trap, while organized lobbying by green-sector firms has the opposite effect.

In the end, the net effect of lobbying depends on which sector is better organized. If brown firms have a lobbying advantage, this produces policy inertia and makes a climate trap more likely. This kind of reasoning invokes cynicism about radical policy change in the US, or the EU, where many established brown firms have huge lobbying operations in Washington DC, and in Brussels. Our framework shows how lobbying may contribute to a long-run climate trap, something static models of lobbying do not pick

up. By altering the development of new technologies and the evolution of values, this could significantly raise the social cost of lobbying over and above standard measures based on static models.

## 5.4 Innovation Subsidies

In the baseline model, politically determined tax policy maximizes the current payoff for parents, but does not take utilities of their children into account. This reflects lack of commitment in the political process. In this subsection, we enrich the policy space in a way that opens the door to “strategic” policymaking where current policy affects future outcomes. Specifically, we allow the government to subsidize innovation in green goods.<sup>17</sup>

This is realistic as many governments pursue such policies (see OECD, 2010, for an overview). We know from Acemoglu et al (2012) that a temporary innovation subsidy can move the economy to a new trajectory by crossing a tipping point. But we do not know whether offering such a subsidy is consistent with political equilibrium.

**Policy objective** Let  $b$  denote an ad valorem subsidy to hiring green-sector scientists so that the per-scientist cost becomes  $\omega(1 - b)$  and the total subsidy cost  $\omega b \mu n$ . Given the separable production structure across periods (and quasi-linear utility), we can write the intertemporal policy objective as

$$\sum_{s=0}^{\infty} \beta^s \widehat{W}(q_s, Q_s, q_s, b_s),$$

where

$$\widehat{W}(q_s, Q_s, \mu_s, b_s) = \mu_s u(q_s, Q_s) + (1 - \mu_s)U(q_s, Q_s) - \omega b \mu_s n_s$$

and  $U(q_s, Q_s)$  and  $u(q_s, Q_s)$  are defined in (18) and (19). This is Utilitarian welfare net of the subsidy costs when the tax rates on both goods have already been optimally chosen in each period. These taxes do not vary with the investment subsidy.

Since the subsidy will lower the per-scientist cost for green goods firms from  $\omega$  to  $\omega(1 - b)$ , the growth rate of green-good quality becomes

$$g(\mu'/(1 - b)) = \left[ \frac{\varphi \sigma \chi^{1 - \frac{1}{\sigma}} \mu'}{\omega(1 - b)} \right]^{\frac{\varphi}{1 - \varphi}},$$

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<sup>17</sup>Similar issues would arise if we considered direct public investments in R&D.

which is increasing in  $b$ . The cost of a subsidy needed to generate this growth rate is  $b\mu\omega qg(\mu'/1-b)^{\frac{1}{\varphi}}$ .<sup>18</sup>

To study the optimal innovation subsidy, note that the value function associated is given by

$$w(\mu, Q, q) \equiv \max_{b \geq 0} \{ \hat{W}(\mu, Q, q) - b\mu\omega(qg(\mu'(b), b))^{\frac{1}{\varphi}} + \beta w(\mu'(b), Q[1 + (G(\mu'(b), \lambda))^{\varphi}], q[1 + g(\mu'(b)/(1-b)]) \} \}, \quad (26)$$

where  $\mu$  is the evolving state variable. Equation (26) is written so that  $\mu'$  depends on  $b$  through (9). Product qualities also depend on  $b$  – through (20). Political parties can thus influence future outcomes via their choice of innovation subsidy. But as politics maximize Utilitarian welfare at any date, they pursue a consistent objective.

**The equilibrium innovation subsidy** To derive the optimal subsidy, we maximize  $w(\mu, Q, q)$  defined in (26) with respect to  $b$ , restricting our attention to non-negative solutions.<sup>19</sup> Three elements determine the optimal subsidy. The first is the responsiveness of innovation to the subsidy which depends on  $1/(1-\varphi)$ . The second is that a subsidy can “correct” firms’ focus on profits rather than total welfare, a wedge that depends on the markup rate  $1/(1-\sigma)$ . The third element is more novel: when green-sector firms invest to raise quality, they influence future environmental values, which further encourages green-goods consumption and profits. Individual firms do not internalize this value externality when they innovate, but political parties do when they decide on subsidies. Putting these three elements together gives

**Proposition 5** *The optimal green R&D subsidy is*

$$b = \max \left\{ \frac{\rho - \mu' + \kappa'}{\rho}, 0 \right\},$$

where  $\rho = \frac{1}{1-\sigma} + \mu\varphi$  and “cultural multiplier”  $\kappa' = \frac{\beta}{\omega} \frac{dw}{d\mu'} \frac{d\mu'}{dn}$ .

To understand the result, first ignore the cultural multiplier (set  $\kappa' = 0$ ). Then, a subsidy is justified only when  $\rho > \mu'$ , which is always true for

<sup>18</sup>Recall that  $qg^{\frac{1}{\varphi}}$  green-sector scientists are needed to generate a growth rate of  $g$ .

<sup>19</sup>In principle, a government that wanted to promote a brown future could tax green innovation but we ignore this possibility here.

small enough  $\mu'$ . With firm markups  $1/1 - \sigma$  (and  $\sigma < 1$ ) a subsidy is needed to offset firms underestimating the R&D benefits by maximizing profit rather than consumer welfare. But as environmental values become more wide-spread ( $\mu'$  goes up), such subsidies become more costly for the current generation which have to finance them.

The cultural multiplier,  $\kappa'$ , reflects how a green-innovation subsidy can be used to influence societal values. This happens in two ways, which can be seen in (26). The first way runs through the effect of environmental values on welfare,  $w_\mu$ , which has the same sign as  $\Delta'$ . If the subsidy makes more people green and this group has a cultural-fitness advantage,  $\Delta' > 0$ , then voters collectively would like to subsidize green investment. But in a climate trap,  $\Delta' < 0$ , this effect makes a subsidy less valuable. The second way the subsidy shapes the cultural multiplier is via the expression  $w_Q \partial Q' / \partial \mu' + w_q \partial q' / \partial \mu'$  which is ambiguous in sign. This expression captures whether a higher  $\mu$  reduces brown-goods innovation and raises green-goods innovation.

Due to these potentially countervailing effects, there is no straightforward result for the sign of  $\kappa'$ . The cultural multiplier can thus either boost or dampen the other effects of the subsidy. But it is a “multiplier” affecting the pace of change rather than a “game changer.” To guarantee positive green innovation subsidies would require policy to fall into the hands of those who care more than voters about a green future.

**Implications** An investment subsidy affects the dynamic path via the growth rate of green goods. The new expression governing the cultural dynamics becomes

$$\delta(\mu, q/Q, \lambda) = \frac{q}{Q} \cdot \frac{1 + g(\mu/(1-b))}{1 + G(\mu, \lambda)} - \left[ \frac{\chi}{\chi + \lambda} \right]^{1-\sigma}.$$

The larger is  $b > 0$ , the higher is green growth, which lowers the chance that society is stuck in a climate trap. However, a larger  $b$  is more likely when  $\Delta' > 0$ . Hence, endogenously chosen innovation subsidies may decrease the likelihood of a climate trap, but this is more likely with a large and positive cultural multiplier.

If  $\Delta' < 0$ , the bulk of citizens value brown over green lifestyles and politics follow that preference. The dynamic perspective does not fundamentally change the constraints on policy imposed by electoral politics. That said, an interesting possibility is a polity close to a tipping point where an innovation

subsidy implies  $\Delta' > 0$  even though  $\Delta < 0$ . This instrument thus allows policymakers to reverse the direction of an economy, which is on its way to a brown steady state.

The strategic policy assumes that voters understand that political decisions can internalize the externality from green investment on values. This requires a certain degree of farsightedness and rationality. If voters were more behavioral, green-innovation subsidies may not emerge in electoral politics.

## 6 Conclusions

We propose a framework where the coevolution of values, technology, and politics shapes society’s dynamic path and long-run outcome. Our motivation is the climate emergency, where certain kinds of production and consumption contribute disproportionately to carbon emissions. Government policies are endogenous to politics, but subject to a credibility problem: current generations may care about the future and politicians may internalize their caring, but they cannot commit future policymakers. This limits the capacity of current generations to internalize the effect of future policy on the evolution of values and technologies.

Our baseline model is formulated around a dynamic complementarity. Technologies and values interact in a non-linear fashion, creating divergent dynamics along two alternative paths – one with changing values and economic transformation, another with a status quo and growing emissions. Around tipping points (critical junctures), small changes can have non-marginal long-run consequences. Our analysis highlights how different features of economics and politics shape the dynamics, including a case when strategically set policies can influence future welfare.

The incorporation of several natural extensions illustrates that our framework is a versatile tool to study the interplay of politics, technologies, and values. Another natural extension would be to add motivated environmental entrepreneurs running some green-goods firms. This would promote green structural change in a similar way as the motivated inventors in Section 5.2. In a richer model with private savings and portfolio investments, environmental citizens may also “boycott” investments into brown-goods firms, thus driving apart the innovation costs of brown- and green-goods firms.

It would be interesting to analyze in detail stock and time-related aspects of the climate externality. An economy may structurally change towards

green consumption, but the transition may not be fast enough to avoid a climate disaster (see Aghion et al, 2012 in the case of exogenous policy). We could also consider investments and actions that act directly on pollution damages ( $\lambda$  in our model). The global nature of climate externalities among interacting multiple policymakers also merits further analysis. Spillovers in both technology and values may affect sustainable paths. For example, promotion of green technologies in one country could generate positive global spillovers (which could be further strengthened by coordinated international action).

Our model highlights the need to bring politics into the formal study of climate dynamics and policy. While green R&D subsidies and brown-goods taxes could change a society's trajectory, this may not materialize when policy is endogenous. However, paying attention to equilibrium policymaking does not mean being a prisoner of political forces. Indeed, our model suggests that politics itself can change by empowering climate activists and scientists, reducing the influence of brown lobbies, or increasing the weight on environmentalists' views in policy. This reinforces the importance of studying political incentives in debates about the dynamics of values and technology.

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# Appendix

## A Additional Material

**Socialization** One way to derive (9) in Section 4.1 is to assume a process of family-based socialization, as in Bisin and Verdier (2001) and Tabellini (2008). Here, we follow the same family-based approach as in Besley (2017). All children have two parents and parents have two children. Reproduction follows a matching process, where a fraction  $v$  of matching is assortative – i.e., parents have the same identity. The remaining fraction  $1 - v$  are randomly matched, which results in some mixed-identity couples. To simplify, we assume two parents of the same type to pass this type on to their children.<sup>20</sup> However, a child with mixed parents may identify as an environmentalist depending on fitness advantage  $\beta\Delta'$  – next period’s expected-utility difference, discounted by factor  $\beta$  – when the child is adult. The child’s identity also depends on a family-specific shock  $\psi$  with infinite support and distribution function  $F(\cdot)$ , which is symmetric around a zero mean with density  $f(\cdot)$ . A mixed-parent child becomes an environmentalist if  $\beta\Delta' \geq \psi$ , so the probability of this event is  $F(\beta\Delta')$ . With a continuum of families, this is the proportion of environmentalist children of mixed parents. Note that  $F(\cdot)$  increases smoothly in  $\Delta$  with  $F(0) = 1/2$ . This yields

$$\mu' = \mu + (1 - v) 2\mu(1 - \mu) \left[ F(\beta\Delta') - \frac{1}{2} \right]. \quad (27)$$

To interpret this expression, note that assortatively matched couples preserve the proportion of environmentalists. Among the randomly matched, a fraction  $\mu^2$  involve two environmentalists. The fraction of mixed-parent households is therefore  $2\mu(1 - \mu)$ . Defining  $\varkappa = (1 - v)$  gives equation (9).

Although we have motivated the model by socialization by parents, a similar story would hold in a wider setting. We could think about peer-group formation at a critical stage of life where people could sort into either homogenous groups or mixed groups. If the mixed groups were more open to change, social mixing would again drive the dynamics.

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<sup>20</sup>This is clearly a strong assumption, adopted here to make the analysis sharper and simpler. One could consider alternatives, such as a fixed “mutation” rate in homogenous groups.

**Alternative dynamics** We now show that there are two possibilities when looking at long-run steady states and the dynamic path towards them given initial conditions  $(\mu, q/Q)$ . The first case is where an economy always ends up in a green steady state. The condition for this is given in:

**Proposition A1** *If  $g(\underline{\mu}) > G(\underline{\mu}, \lambda)$ , then societal values always converge to  $\mu = \bar{\mu}$  for all  $\mu_0 \in [\underline{\mu}, \bar{\mu}]$ . Depending on initial conditions, values may not evolve monotonically along the equilibrium path.*

**Proof.** The result is obvious if  $\delta(\mu, q/Q, \lambda) > 0$  since  $\mu_s > \mu$  for all  $s > 0$  using (9) and (21). So now consider the case where  $\delta(\mu, q/Q, \lambda) < 0$ . Observe first that if  $g(\underline{\mu}) > G(\underline{\mu}, \lambda)$ , then  $g(\mu) > G(\mu, \lambda)$  for all  $\mu \geq \underline{\mu}$ . Thus  $q/Q$  is an increasing sequence in  $s$ . However,  $\mu$  need not be. But  $\delta_s = \delta(\underline{\mu}, q_s/Q_s, \lambda)$  is increasing in  $s$  and there exists  $\widetilde{q/Q}$  such that  $\delta(\underline{\mu}, \widetilde{q/Q}, \lambda) = 0$ . Hence there exists  $\tilde{s}$  such that  $\delta_{\tilde{s}} > 0$  for all  $q_{\tilde{s}}/Q_{\tilde{s}} > \widetilde{q/Q}$ . Then (9) implies that  $\mu_s$  is an increasing sequence for all  $s > \tilde{s}$ . The result holds a fortiori, if there exists  $\mu_s > \underline{\mu}$  such that  $\delta(\mu_s, q_s/Q_s, \lambda) > 0$ . ■

This case is interesting as it can be thought of as a case where economics and politics together allow a country to escape the climate trap. It will hold if the Pigouvian tax on brown goods is large enough, so that even with a small market for green goods, there are stronger incentives to invest in green rather than brown goods. In this case, we could begin with  $\delta(\mu, q/Q, \lambda) < 0$  which means that cultural dynamics are unfavorable to combatting climate change. However, things will eventually turn around since  $q/Q$  will increase over time to a point where  $\delta(\mu, q/Q, \lambda) > 0$  and now values will change in the green direction, driven by technological progress.

**Political objectives with lobbying** Given our assumptions in Section 6.3, we assume that the coalition of green firms agrees on contributions that maximize the expected profits of a typical green-variety firm

$$E(\pi) = z^A \pi(t^A) + (1 - z^A) \pi(t^B) - \frac{1}{2} [(c^A)^2 + (c^B)^2].$$

Using (25), this gives optimal green-firm contributions as

$$c^A = \max\{0, X \sqrt{\xi} [\pi(t^A) - \pi(t^B)]\} \quad \text{and} \quad c^B = \max\{0, X \sqrt{\xi} [\pi(t^B) - \pi(t^A)]\}. \quad (28)$$

In words, a firm only pays to the one party whose policy yields higher profits. By a similar argument, optimal brown-variety contributions are

$$C^A = \max\{0, X\sqrt{\xi}[\Pi(T^A) - \Pi(T^B)]\} \quad \text{and} \quad c^B = \max\{0, X\sqrt{\xi}[\Pi(T^B) - \Pi(T^A)]\}. \quad (29)$$

Next, we substitute the optimal contributions in (28) and (29), integrate these up over all firms, and substitute the result into (25) to get

$$z^A = \frac{1}{2} + X\{\Gamma(T^A, t^A, T^B, t^B, \mu) + X\xi[\phi\mu(\pi(t^A) - \pi(t^B)) + \Phi(1 - \mu)(\Pi(T^B) - \Pi(T^A))]\}. \quad (30)$$

Compared to (15), the third term now adds a weighted average of profits in the two sectors. Hence the optimal strategy will no longer be Utilitarian, as in the baseline model. This reflects the (rational) expectation that a policy boosting profits in a sector will generate contributions from its lobbying coalition, which – in turn – will help the party win the election. As party  $B$  maximizes  $1 - z^A$ , it once again faces a symmetric problem to  $A$ .

Finally, we derive the implications of the model. First, substitute from equations (4) and (5) for equilibrium profits into the political objective (30). Maximizing the resulting expression with respect to the two policy instruments, we can carry out the steps in the proof of Proposition 4 below.

## B Proof of Propositions

**Proposition 1 Proof.** To prove this, we first solve for the optimal tax rate on brown-good varieties. The key observation is that – substituting from (4), (5), and (6)-(8) – we can write each party’s problem as maximizing

$$\mu v(t, T, q, Q, \mu) + (1 - \mu) V(t, T, q, Q, \mu) = \mu \left[ \frac{qy^{1-\sigma}}{1-\sigma} - \chi y \right] + (1 - \mu) \left[ \frac{QY^{1-\sigma}}{1-\sigma} - \chi Y \right] - \lambda(1 - \mu) Y.$$

The optimum with respect to  $T$  satisfies

$$(1 - \mu) \left[ \frac{\partial \left[ \frac{QY^{1-\sigma}}{1-\sigma} - \chi Y \right]}{\partial T} - \lambda \frac{\partial Y}{\partial T} \right] = (1 - \mu) \left[ \frac{\sigma\chi + T}{1 - \sigma} - \lambda \right] \frac{\partial Y}{\partial T} = 0.$$

Solving for  $T$  yields the result. Analogously, for  $t$ , the optimum condition is

$$\mu \left[ \frac{\partial \left[ \frac{qy^{1-\sigma}}{1-\sigma} - \chi y \right]}{\partial t} \right] = \mu \left[ \frac{\sigma\chi + t}{1-\sigma} \right] \frac{\partial y}{\partial t} = 0$$

and solving for  $t$  gives the result. ■

**Proposition 2 Proof.** To see this, note that if  $\delta \left( \mu, \frac{q}{Q}, \lambda \right) > 0$ , we have  $\mu' \geq \mu$ , from (9) and (21), with strict inequality if  $\mu > \underline{\mu}$ . Moreover, from (??)  $\frac{q'}{Q'} \geq \frac{q}{Q}$  with strict inequality if  $\mu > \underline{\mu}$ . By induction, this implies that  $\delta \left( \mu', \frac{q'}{Q'}, \lambda \right) > \delta \left( \mu, \frac{q}{Q}, \lambda \right)$ , and thus  $\mu \geq \mu'$  for all future time periods. A parallel argument establishes that  $\mu_s$  is a decreasing sequence if  $\delta \left( \mu, \frac{q}{Q}, \lambda \right) < 0$ . ■

**Proposition 3 Proof.** Obvious from the text. ■

**Proposition 4 Proof.** To show this, observe that (using the envelope condition)

$$\pi_t(t) = -y(t)$$

and

$$\Pi_T(T) = -Y(T).$$

Carrying out the same steps as in the proof of Proposition 1, we get the first order condition

$$\mu \left[ \frac{\sigma\chi + t}{1-\sigma} \right] \frac{\partial y}{\partial t} - \mu\xi\phi y(t) = 0.$$

Now observe that

$$\frac{y}{\partial y / \partial t} = -\sigma(\chi + t).$$

Then the optimal tax/subsidy solves

$$\left[ \frac{\sigma\chi + t}{1-\sigma} \right] + \sigma\xi\phi(\chi + t) = 0.$$

Similarly, the optimum with respect to  $T$  satisfies

$$(1-\mu) \left[ \frac{\sigma\chi + T}{1-\sigma} - \lambda \right] \frac{\partial Y}{\partial T} - (1-\mu)\xi\Phi Y(t).$$

Noting that

$$\frac{Y}{\partial Y / \partial T} = -\sigma (\chi + T)$$

yields

$$\left[ \frac{\sigma \chi + T}{1 - \sigma} - \lambda \right] + \sigma (\chi + T) \xi \Phi = 0.$$

■

**Proposition 5 Proof.** The formula for the optimal subsidy is given by the first-order condition when maximizing (??) with respect to  $b_s$

$$-\mu \omega n - b \mu \omega \frac{\partial n}{\partial b} + \beta \frac{dw}{d\mu'} \frac{d\mu'}{dn} \frac{\partial n}{\partial b} + \beta \frac{\partial w}{\partial q'} \frac{\partial q'}{\partial n} \frac{\partial n}{\partial b} = 0,$$

which we can rewrite as

$$-\frac{\mu \omega n}{\partial n / \partial b} - b \mu \omega + \beta \frac{dw}{d\mu'} \frac{d\mu'}{dn} + \beta \frac{\partial w}{\partial q'} \frac{\partial q'}{\partial n} = 0.$$

We observe that

$$\frac{n}{\partial n / \partial b} = (1 - \varphi) (1 - b),$$

and that an optimal solution will set  $b$  such that

$$\beta \frac{\partial w}{\partial q'} \frac{\partial q'}{\partial n} = \beta \mu' \frac{\partial q'}{\partial n} \frac{(y')^{1-\sigma}}{1 - \sigma}.$$

The profit-maximizing condition for investment in quality is

$$\beta \mu' \frac{\partial q'}{\partial n} (y')^{1-\sigma} = \omega (1 - b),$$

which implies

$$\beta \frac{\partial w}{\partial q'} \frac{\partial q'}{\partial n} = \frac{\omega (1 - b)}{1 - \sigma}.$$

If we define

$$\kappa' = \frac{\beta}{\omega} \frac{dw}{d\mu'} \frac{d\mu'}{dn},$$

the optimal subsidy formula becomes

$$-\mu [(1 - b) (1 - \varphi) + b] + \kappa' + \frac{(1 - b)}{1 - \sigma} = 0.$$

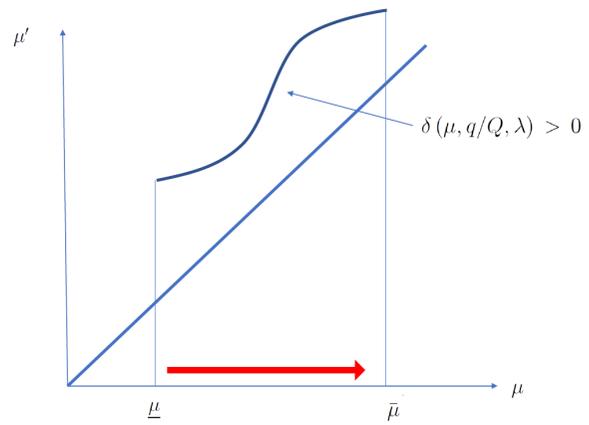
Solving for  $b$  yields

$$b \left[ \frac{1}{1-\sigma} + \mu\varphi \right] = \kappa' + \frac{1}{1-\sigma} + \mu(1-\varphi),$$

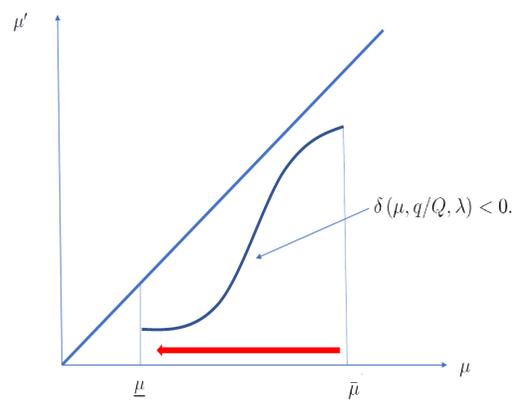
such that

$$b = \max \left\{ \frac{\kappa' + \rho - \mu}{\rho}, 0 \right\}$$

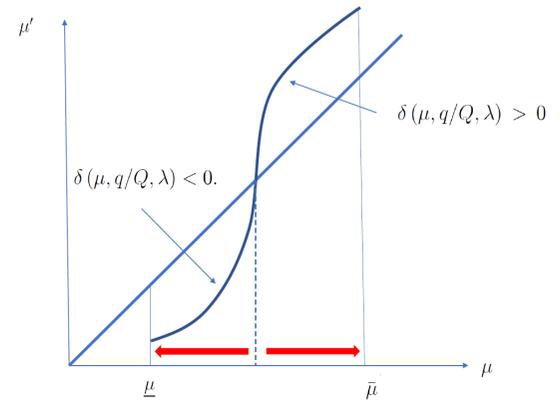
where  $\rho = \frac{1}{1-\sigma} + \mu\varphi > 0$ . ■



Panel A



Panel B



Panel C

Figure 1