DISCUSSION PAPER SERIES

DP17242

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Tim Besley and Torsten Persson

POLITICAL ECONOMY

PUBLIC ECONOMICS

CEPR

ISSN 0265-8003

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Discussion Paper DP17242
Published 23 April 2022
Submitted 19 April 2022

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

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Abstract

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JEL Classification: N/A

Keywords: N/A

Tim Besley - t.besley@lse.ac.uk
LSE and CEPR

Torsten Persson - torsten.persson@iies.su.se
IIES, Stockholm University and CEPR

Acknowledgements
We are grateful for perceptive comments by Philippe Aghion, David Baron, Xavier Jaravel, Bård Harstad, Elhanan Helpman, Matthew Kahn, Gilat Levy, Linus Mattauch, and Jean Tirole, as well as numerous seminar and webinar participants. We also thank Azhar Hussain and Linchuan Xu for research assistance. Financial support from the ERC and the Swedish Research Council is gratefully acknowledged.

The Political Economics of Green Transitions*

Timothy Besley† and Torsten Persson‡

February 2022

Abstract

Reducing the emissions of greenhouse gases may be almost impossible without a green transition – a process of radically changing consumption and production patterns. We put forward a dynamic model, where switches in consumption and production create a dynamic externality that can help or hinder a green transition. In democratic societies, governments cannot commit to future policy paths and must aggregate conflicting interests across different voters. Moreover, democratic politics include a range of informal activities, firm lobbying, as well as activist protests against brown firms and promotions of green firms. These different aspects of politics constrain feasible policies. We ask whether, and under what circumstances, the interaction of political forces and market forces bring about a green transition.

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†LSE, t.besley@lse.ac.uk.

‡IIES, Stockholm University, torsten.persson@iies.su.se

1 Introduction

Many believe that limiting the risk of an environmental disaster will require a radical structural transformation of production and consumption patterns. We refer to such a process as a *green transition,* where firms gradually switch towards producing goods with green technologies while households switch towards consuming those green alternatives. Despite an emerging consensus on the need for such transformative change, different observers hold a variety of views on how to best achieve it.

However, the dominant view among economists goes back to Pigou (1920) and sees the solution in the form of a "big, fat tax" – the only questions being the optimal level and time profile of that tax. Two postulates underpin this view. First, the feasible route to a green transition goes solely through *extrinsic* incentives, specifically a change in prices.[1] Second, the analysis is *normative* and reflect the optimal dynamic choices of a social planner. This paper relaxes both of these postulates.

Intrinsic *and* extrinsic incentives We consider an alternative route to a green transition via *intrinsic* incentives. Almost fifty years ago, prominent commentators like Ernst Friedrich Schumacher exhorted Western countries to change their lifestyles due to their environmental consequences (Schumacher, 1973). Concerns about climate change have reinvigorated such debates in light of apparent inertia among households, firms and governments.[2]

In our view, it is useful and plausible to think about demand patterns reflecting both prices and values, where some consumers care intrinsically about the environmental consequences of their choices. This allows a sharper characterization of a green transition as a process where the share of those who hold green values rises over time, which alters the profitability of using green technologies.

The key contribution of the paper is to build a tractable model with endogenously evolving values, consumption and production. This model lays bear the logic of the argument and hence the challenge posed by a green transition poses, including the possibility of a welfare inferior trap where the transition does not take place.

[1] The next section relates our approach to existing research in this and several other dimensions.

[2] See, for example, Peattie (2010) and O'Rourke and Lollo (2015).

Though we emphasize endogenous values, we model them as being (partly) rooted in underlying economic incentives; when it is costly to hold green values, fewer people acquire them or more people abandon them. These incentives also reflect decisions by firms which technologies to use and which prices to charge. The green transition – at its very heart – thus involves a complementarity between choices by producers and consumers, akin to that associated with platform technologies (Rochet and Tirole 2003). If more firms go green, more households go green, and vice versa.

Positive scope We also question the standard policy approach based on an omnipotent social planner maximizing a social-welfare function with full commitment to a future policy path. Instead, we take a positive approach where environmental policies are determined by political forces. We then ask whether incentive-compatible policies are capable of supporting a green transition. In addition to electoral politics, we incorporate the role of organized lobbying by firms as well the behavior of activists. Whether they are movements like the *gilets jaunes* in France or the lobbyists and NGOs at COP26, they are a critical part of the policy landscape. Politically determined policies also lack commitment to future policy, as vividly illustrated by President Trump's decision to pull out of the Paris Accord signed by President Obama.

Refocusing the analysis from normative to positive shifts the perspective on the role that policy can realistically play in a green transition. Rather then being the main driver, policy becomes a facilitator of a process which has its roots in interdependent private actions by consumers and firms.

The four steps of our argument Our analysis begins with a baseline laissez-faire model, which allows for shifting consumption and production patterns. Individual citizens hold either green (environmental) or brown (materialist) values. Forward-looking socialization – based on expected utility – can alter these values, which shape consumption patterns and policy preferences. Firms make a forward-looking decision – based on expected profit – whether to use a green or brown technology. This setting can result in a "trap" – welfare would be higher on an alternative path, but no green transition occurs and the emissions problem gets worse over time.

We then study a standard electoral model where two parties compete on policy platforms for taxes (or subsidies) on brown and green goods. These policies can affect static resource allocation and influence the dynamics produced by markets forces. However, an incentive-compatible policy path may not suffice to induce a green transition, even though this is the long-run desirable outcome. We also consider the implications of lobbying by brown and green firms. Electioneering and lobbying set the conditions for the dynamic coevolution of technologies and preferences, and may therefore help or hinder a green transition.

In this baseline model, policies and politics do not truly interact over time with the shares of green and brown producers. In a subsequent step, we study *dynamic* political forces, via which incentive-compatible policies change over time and reinforce the dynamics in the private sector. We consider three mechanisms. In the first, green shares help shape equilibrium policy; in the second, green shares affect "private politics" – extra-political political actions; in the third, current policy influences future green shares as policymakers are forward-looking.

In the final step, we endogenize the cost of switching from brown to green technologies due to profit-maximizing innovation. This introduces elements of directed technical change and shows how incentives to innovate interact with consumption and production decisions as values change.

Outline of the paper The approach relates to prior research in several different literatures and Section 2 briefly spells out these links. We then turn to our formal analysis. Section 3 lays out our laissez-faire baseline model of static choices in consumption and production as well as dynamics of values and technologies. Section 4 brings in policy interventions and studies how electoral competition and lobbying shape taxes (subsidies) on green and brown goods, which alter static private choices as well as the dynamics of tastes and technologies. Section 5 brings in mechanisms – a richer role of green values, political activism by individual green consumers, and a richer set of policy instruments – that make politics dynamically interact with values and technologies. Finally, Section 6 includes the extension with innovation-supported declining costs of brown-to-green technology conversion. Section 7 concludes. Some analytical details and proofs of propositions can be found in a (Web) Appendix.

2 Forerunners

Our work relates to different lines of research in economics and other social sciences. We now sketch these relations without attempting an exhaustive literature review.

Our baseline model of values in Section 3 – and the whole paper – links to a growing economics literature about green consumer demands. Part of this research posits that consumers wish to express green values. For instance, Nyborg et al. (2006) model how green consumers emerge out of pro-social, self-image motives, while Delmas et al (2017) find that this is a way to understand the demand for electric vehicles and solar panels. Andre et al (2021) survey a representative sample of 8,000 U.S. adults, finding that perceived social norms raise the willingness to take individual action to prevent global warming. Related contributions include imaginative work by Bezin (2015, 2019), who studies the interplay between green values and innovation. Mattauch et al. (2018) consider policy implications of endogenous values.

Our approach to values is rooted in an earlier literature on cultural evolution beginning with Boyd and Richerson (1985) and Cavalli-Sforza and Feldman (1981) – Bisin and Verdier (2011) review economic applications.[3] When values change so do economic and policy preferences. Following Akerlof and Kranton (2000), we model this as the formation of green (environmentalist) vs. brown (materialist) identities. While this approach has a long history in sociology and social psychology, it is more recent in economics.[4] We develop the dynamic approach in Besley and Persson (2019a), by having a dual transition of production and consumption decisions as values change.

Our approach to environmental policy in Section 4 relates to existing research on policies to fight pollution and global warming. Dasgupta and Heal (1979) is a classic exposition of the Pigouvian approach. Seminal applications to climate change such as Nordhaus and Boyer (2000) and Golosov et al. (2014) add a carbon-cycle *cum* global-warming bloc to a neoclassical growth model. These authors consider dynamic Pigouvian taxes set by a social planner with the power to commit (see Hassler and Krusell 2018 for

[3] Bowles (1998) has a general discussion of preference change in economic models. Persson and Tabellini (2020) draw on lessons from several existing literatures in their survey of research on the coevolution of values and institutions.

[4] See Bowles (1998) for a general discussion of preference change in economic models. Persson and Tabellini (2020) draw on lessons from several existing literatures when surveying research on the coevolution of values and institutions.

an overview). Damages are related to the cumulated stock of past emissions, something that we do not consider here.

Our analysis of static political forces in Section 4 links to earlier work on environmental politics (see Oates and Portney 2003 for an early review). For example, Cragg et al (2013) find that political ideology strongly links with preferences for environmental regulation. Our paper goes beyond electoral politics to allow for lobbying by brown and green firms, in a way that builds on Baron (1994).

In Section 5, we introduce dynamic political forces through which policy choices interact with private choices of values and technologies. One of these forces is individual political activism by green consumers outside of the political system. In this type of "private politics," activists directly pressure firms for change outside of the political system (see Abito et al. 2019 for a review). Such private action often targets polluting firms that use or produce fossil fuels.

Finally, our extension to endogenous technical change in Section 6, relates to theoretical models of innovation which fall into three main types. (1) New firms innovate in new goods, as in Romer (1990). (2) New firms displace old firms by innovating in existing goods, as in Aghion and Howitt (1992). (3) Existing firms innovate in existing goods, as in Krusell (1998).[5]

A more recent literature studies innovation in green vs. brown technologies, drawing on the modeling in Acemoglu (2002) of endogenous technical change, and on the empirics in Popp (2002) on energy-saving investments and energy prices. Acemoglu et al. (2012) is an early theoretical contribution, with later work by Acemoglu et al. (2016), Aghion et al. (2016), and others. Unlike that research, we allow switching on the consumer side via changing values, on top of the standard mechanism via incentives from relative prices and taxes. While we do not model parallel innovations in green and brown technologies, producers may choose between green and brown inputs from given technologies.

3 A Laissez-faire Benchmark

Our baseline model abstracts from policy interventions and politics. This allows us to isolate a crucial dynamic complementarity between technologies

[5] Garcia-Macia et al. (2019) discuss empirically these different forms of innovation and find that (3) is indeed the most important source of U.S. technological change.

and values and its implications for the possibility of a green transition.

3.1 Consumption and Production

Goods, consumers, and types Each citizen has an exogenous endowment I of a numeraire good whose consumption is denoted by x. The numeraire can be transformed into two kinds of goods, on a continuum of varieties with mass one, indexed by $i \in [0, 1]$. Each variety can thus be produced in a polluting and a non-polluting way. We refer to non-polluting varieties as "green", and polluting ones as "brown", indexing firms $i \in [0, \gamma]$ as green and $i \in [\gamma, 1]$ as brown. In the dynamic analysis to follow, the green share γ changes over time, reflecting forward-looking technology adoption by firms.

At any date, a unit mass of citizens is divided into two types (identities) denoted by $\Gamma \in \{0, 1\}$ where $\Gamma = 1$ represent green consumers and $\Gamma = 0$ brown consumers, with μ denoting the share of green. In the dynamic model, this green share also changes over time, reflecting forward-looking socialization by (cultural or biological) parents.

Preferences and consumption Preferences for consumption are given by

$$\begin{gathered}\tfrac{1}{1-\sigma}\left[\int_0^\gamma \left[\Gamma\left(1+g\right)^\sigma + \left(1-\Gamma\right)\right] y(i)^{1-\sigma} di + \right.\\ \left. \int_\gamma^1 \left[\Gamma\left(1-g\right)^\sigma + \left(1-\Gamma\right)\right] Y(i)^{1-\sigma} di\right] + x - \lambda \overline{Y},\end{gathered} \tag{1}$$

where $\sigma < 1$ govern the substitution elasticity across varieties, and parameter $g > 0$ indexes the preference shift among green consumers favoring green goods y and disfavoring brown goods Y.

The level of pollution is given by $\overline{Y}$, the per-capita consumption of (all) brown goods. For now through Section 5, we suppose that both groups are equally hurt by pollution captured by a parameter $\lambda > 0$. The common budget constraint is

$$I \geq x + \int_0^\gamma p\left(i\right) y\left(i\right) di + \int_\gamma^1 P\left(i\right) Y\left(i\right) di, \tag{2}$$

where again lower-case (upper-case) letters apply to green (brown) goods, x is consumption of numeraire, and I is lump-sum (equal for all consumers) income from a numeraire endowment plus repatriated profits and rents (see below).

Individual demands, by type $\Gamma \in \{0,1\}$, for each variety i follow from (1) and (2). Aggregating the resulting demands across consumers, we get

$$y(i) = [1+\mu g]\, p(i)^{-\frac{1}{\sigma}}, \quad Y(i) = [1-\mu g]\, P(i)^{-\frac{1}{\sigma}}. \tag{3}$$

These expressions reflect the fact that green consumers have stronger (weaker) demands for green (brown) goods, all else equal. The market demand for each green (brown) variety thus goes up (down) in the share of green consumers – these effects are larger for larger value-induced taste differences g.

Technologies and production We focus on a symmetric equilibrium, where prices and production levels are the same across all green varieties and all brown varieties, respectively. Thus we remove index i when we study the static choices within each group of goods. Firms produce output using *either* clean/green or dirty/brown (numeraire) inputs. Clean inputs are more expensive with the marginal cost of brown goods χ being lower than that of green goods $\chi+\zeta$, $\zeta > 0$. Firm i can decide to go green in the next period at cost mi (see below).

Each variety of the good is monopolized. In the current period, firms produce their variety with the technology they chose last period. They set prices to maximize profits. Standard arguments show that optimal pricing implies a fixed mark up over marginal cost

$$P = \frac{\chi}{(1-\sigma)} < p = \frac{\chi+\zeta}{(1-\sigma)}. \tag{4}$$

Thus the higher private production cost of green goods are reflected in a higher price to consumers

Profits Profits are

$$\pi(i) = \sigma\kappa(\zeta)[1+\mu g] - S[mi], \;\; \Pi = \sigma\kappa(0)[1-\mu g] - S[mi]. \tag{5}$$

Given the different consumer preferences, a higher share of green consumers μ implies a higher (lower) market share for green (brown) goods and thus higher (lower) profitability – the terms in square brackets. In the profit expressions, $\kappa(x) = ((\chi+x)/1-\sigma)^{1-\frac{1}{\sigma}}$ is a decreasing function (as $\sigma < 1$).

The term $S[mi]$ is a binary cost indicator, reflecting whether firm i adopts a green technology for the next period. Producing in a green way requires a fixed input, the amount of which varies by firm. In particular, the cost of accessing a green rather than brown technology is mi per period. We thus order the firms by their per-period fixed costs for going green. It is natural to interpret this cost as a licensing fee for using the green technology. Rents from these fees are paid out to citizens (as part of I).

Section 6 microfounds this approach. There, we allow the prospective rents from licensing new technologies charged to spur innovation in green technologies. In that setting, successful innovation drives down m over time.

3.2 Dynamics

Time is infinite, discrete, and indexed by s. When there is no risk of confusion, we use the short-hand notation z for z_s and z' for z_{s+1}.

Timing Each period has four stages:

1. Given shares of green consumers μ and green firms γ enter the period.
2. Price-setting, production and consumption decisions take place.
3. Technology adoption by firms determines γ'.
4. Socialization by consumers determines μ'.

In this way, the green shares of consumers and producers evolve over time. We solve the model backwards.

Socialization – consumers going green We assume that values of consumers – i.e., if they identify as green or brown – develop according the "fitness advantage" of holding green rather than brown values, as well as some random factors. In the Appendix (see Section A1), we give an example of a particular microfoundation for this formulation. It is similar to the forward-looking socialization models with overlapping (or sequential) generations in Bisin and Verdier (2001), Tabellini (2008), and Besley and Persson (2019).

A key driver of the value dynamics is the expected payoff from being green or brown, which depends on the future consumption opportunities for each group. Since each household is atomistic, it takes these opportunities as given. Specifically, denote the (rationally expected) gain from holding green, rather than brown, values at $s+1$ by $\Delta' \gtreqless 0$. When $\Delta' > 0$ green consumers thrive relative to brown consumers and vice versa.

In the Appendix, we show that the growth rate of green consumers can be approximated – to a first-order – by:

$$\frac{\mu' - \mu}{\mu} = \varkappa \Delta', \tag{6}$$

where $\varkappa > 0$ reflects underlying socialization conditions such as social mixing. The growth of green values, and of green consumption, is thus positive (negative) iff green values have (do not have) a fitness advantage – i.e., $\Delta' > 0$ (< 0).

Using (1), (3), and (4), we obtain

$$\Delta' = \widehat{\delta}(\gamma') = \frac{\sigma g}{1-\sigma}\left[\gamma' \kappa(\zeta) - (1-\gamma')\kappa(0)\right]. \tag{7}$$

Equilibrium fitness of green values thus increases linearly in the expected share of green goods.

Technology adoption – producers going green Being too small to influence aggregate outcomes, each firm takes future market shares, which depend on μ', as given. Using (5) one period ahead – and ignoring discounting to keep things simple – we find that firm i uses the green technology next period if

$$\sigma\left(\mu' g\left[\kappa(\zeta) + \kappa(0)\right] + \left[\kappa(\zeta) - \kappa(0)\right]\right) \geq mi. \tag{8}$$

We assume that $(1+g)\kappa(\zeta) - (1-g)\kappa(0) < m/\sigma$, so that some brown production takes place even if $\mu = 1$. A firm will go green either if its cost of doing so (proportional to i) is low enough, or the share of green consumers μ' is large enough. The equilibrium share of green firms γ' – defined by the firm whose profits as green and brown are equal – becomes

$$\widehat{\gamma}(\mu') = \max\left\{0, \sigma\frac{(1+\mu' g)\kappa(\zeta) + (1-\mu' g)\kappa(0)}{m}\right\}. \tag{9}$$

This share is linearly increasing in μ' (for interior shares), a relation akin to the *market-share effect* in the literature on green-brown directed technical change (Acemoglu and Linn 2004). Note that a lower value of m or ζ, and a higher value of g, all lead to a larger fraction of green goods for any μ'. But for

$$\mu' < \frac{[\kappa(0) - \kappa(\zeta)]}{\sigma g [\kappa(\zeta) + \kappa(0)]} \tag{10}$$

there is no green production at $s+1$. The prospective market for green goods is too small and unprofitable for any firm to adopt the green technology. Because of the green-goods cost disadvantage ζ, this is always true for $\mu' = 0$.

A dynamic complementarity Putting the pieces together, we get the following expression for equilibrium fitness of green values

$$\Delta' = \delta(\mu) = \widehat{\delta}(\widehat{\gamma}(\mu')). \tag{11}$$

As $\widehat{\delta}$ and $\widehat{\gamma}$ are continuous and (weakly) increasing functions, so is $\delta(\mu)$. This reflects the dynamic complementarity mentioned above; a future green technology is more profitable if producers expect more future green consumers (the market-share effect). At the same time, if more firms go green, then the expected-utility difference between holding green and brown values goes up. Therefore, more consumers decide to go green, as shown in (6).

Which steady state? This dynamic complementarity leads to divergent value dynamics. The economy can thus either converge to a green steady state at $\mu = 1$, or a brown steady state at $\mu = 0$. To see this, use (9) and (7) to derive a closed form for continuous function δ, namely

$$\Delta' = \delta(\mu) = \max\left\{-\frac{\sigma g \kappa(0)}{1-\sigma}, \delta_0 + \delta_1 \mu'\right\}, \tag{12}$$

where

$$\delta_0 = \frac{\sigma g}{1-\sigma}\left[\frac{\sigma[\kappa(\zeta)^2 - \kappa(0)^2]}{m} - \kappa(0)\right] < 0, \tag{13}$$

and

$$\delta_1 = \frac{\sigma^2 g^2}{1-\sigma}\frac{[\kappa(\zeta) + \kappa(0)]^2}{m} > 0. \tag{14}$$

The fact that $\delta_0 < 0$ follows from $\zeta > 0$, the higher marginal cost of producing green goods.[6]

[6] We assume that $\varkappa$ is small enough such that $\delta_1 \varkappa < 1$.

We assume that technology and taste parameters (ζ, m, and g) are such that $\delta(1) = \delta_0 + \delta_1 > 0$, so that a green transition is feasible. This assumption requires a positive expected relative fitness of being green, when everyone else is green. From (12), we know that $\delta(0) < 0 < \delta(1)$. Given $\delta_\mu(\mu) \geq 0$ and continuity of $\delta(\mu)$, the opposite-signed extreme values (by the intermediate-value theorem) imply a critical value of μ defined by $\delta(\hat{\mu}) = 0$ where the relative fitness of green values is zero. This and the positive feedback dynamics gives us:

Proposition 1 *If $\delta_0 + \delta_1 > 0$, a laissez-faire economy converges to a green (brown) steady state with $\mu = 1$ ($\mu = 0$) if and only if initial green values are large (small) enough that $\mu \geq -\frac{\delta_0}{\delta_1}$ ($\mu < -\frac{\delta_0}{\delta_1}$).*

Even though there are two steady states, the dynamics are unique. If the initial share of green consumers is small enough, few producers find it optimal to produce green goods. The inability to consume green goods makes it unattractive to be a green consumer, so the green-values share is shrinking and the economy converges to a brown steady state.

Slope and level effects Equation (12) illustrates the forces that shape the dynamics. Parameter δ_0 represents a *level effect,* as it determines the vertical position of the $\delta_0 + \delta_1\mu$ curve. Instead, parameter δ_1 induces a *slope effect* on the curve. It also influences the speed of dynamic convergence. We already know from (6) that the growth rate of green values is

$$\frac{\mu' - \mu}{\mu} = \varkappa \Delta'.$$

From (9), the share of green firms grows at the same rate as the share of green consumers.

Figure 1 illustrates the dynamic paths in Proposition 1 using (6) and (7). Though a green transition is feasible, it need not come about. Specifically, green values – and thus green consumption and production – have to exceed critical juncture $\hat{\mu} = -\frac{\delta_0}{\delta_1}$. This is a natural consequence of the market-size effect. If producers do not anticipate a large enough market for green goods, few of them go green. By the dynamic complementarity, few consumers go green, which reinforces the dominance of brown consumers and producers over time. The flat portion of the δ-curve, corresponds to the segment at low levels of μ, where green production is unprofitable

Insert Figure 1 about here

Comparative dynamics We now show how the level and growth effects depend on three parameters: $\{m, \zeta, g\}$. From the definition of δ_1 in (14), the transition towards the long-run steady state is faster the lower are the m and ζ, the costs of green-technology use, and the higher is g, the green-value shift of preferences.

Corollary 1 *Given initial green values μ, a green transition is more likely when m is lower. The slope parameter δ_1 is decreasing in m, ζ and increasing in g, and the level parameter δ_0 is increasing in m and decreasing in ζ.*

In Figure 1, a lower green-technology cost shifts the $\delta(\mu)$ curve up and left – and hence implies a lower critical value $\hat{\mu}$. Lower technology switching costs and lower marginal costs of green production speed up the green transition, as does a greater preference tilt among green consumers. The reason that δ_0 shifts down with higher ζ is that the profits from going green are lower with a higher green marginal cost.

Growth of pollution We can also think about the green transition in terms of economy-wide pollution $\lambda\overline{Y}$. Integrating over the (symmetric) brown firms, the closed-form solution for total (per-capita) brown production is:

$$\overline{Y} = (1-\gamma)(1-\mu g)\kappa(0)^{\frac{1}{1-\sigma}}. \tag{15}$$

The growth rate of pollution is given by:

$$\frac{\overline{Y}' - \overline{Y}}{\overline{Y}} = \frac{(1-\gamma')}{(1-\gamma)}\frac{(1-\mu' g)}{(1-\mu g)} - 1, \tag{16}$$

a non-linear decreasing function of μ' and γ' reflecting the conversion rates of green production and consumption. Evidently, pollution falls whenever these shares rise, so that $\mu' > \mu$ and $\gamma' > \gamma$.

Welfare Since the laissez-faire equilibrium is insensitive to the pollution externality $\lambda\overline{Y}$, there is no reason to expect a market equilibrium to be socially optimal. Of course, this is a standard conclusion in a static model with externalities. But in our dynamic model cultural evolution can make the externality grow or shrink over time as emissions rise or fall on the time path of μ. A green transition mitigates the externality even in the absence of government intervention, as citizens adopt green lifestyles and firms adopt green technologies. This promises a laissez-faire solution to pollution problems.

To study the welfare implications, write current utilitarian welfare in the economy as

$$\omega(\mu) = \mu v(\mu) + (1-\mu)V(\mu) - \lambda Y(\mu) = \mu\delta(\mu) + V(\mu) - \lambda Y(\mu). \tag{17}$$

Here, $v(\mu)$ and $V(\mu)$ are the current-period, equilibrium-welfare levels – including realized demands based on endowments and repatriated profits plus rents, but excluding emission damages – of green and brown consumers, while $Y(\mu)$ is total brown production. We can write intertemporal utilitarian welfare viewed from period s (again, ignoring discounting) as the infinite sum

$$\omega(\mu) + \omega(\mu') + \sum_{\varepsilon=2}^{\varepsilon=\infty} \omega(\mu_{s+\varepsilon}). \tag{18}$$

Consider a (small) change in the fraction of green consumers to period $s+1$ from period s given by $\mu' - \mu$. This alters utilitarian current welfare from s to $s+1$ by approximately

$$\omega_\mu(\mu) \cdot (\mu' - \mu) = [\mu\delta_\mu(\mu) - \lambda Y_\mu(\mu) + \delta(\mu) + V_\mu(\mu)] \cdot (\mu' - \mu). \tag{19}$$

The first two terms in square brackets are unambiguously positive, reflecting higher fitness of green values and lower emissions at a higher share of green consumers ($\delta_\mu(\mu) > 0$ and $-Y_\mu(\mu) > 0$). As for the third term, we know that $\delta(\mu) \lesseqqgtr 0$ as $\mu \lesseqqgtr -\frac{\delta_0}{\delta_1}$. Finally, $V_\mu(\mu)$ is unambiguously negative and proportional to $\kappa(\zeta) - \kappa(0) < 0$ – brown consumers dislike more green goods (ignoring the externality) as green (private) marginal costs are higher by ζ.

Thus, a rising share $\mu' > \mu$ can raise current utilitarian welfare at a green consumer share below critical value of $-\frac{\delta_0}{\delta_1}$, if emission cost λ is high enough relative to green-goods production inefficiency ζ. The same would be true in the next period, as $\delta(\mu) < 0$ would be smaller in absolute value. An economy with $\mu < -\frac{\delta_0}{\delta_1}$ can thus be in a trap where it would be better to move towards the green steady state ($\mu' > \mu$), but market forces are moving the economy towards the brown steady state ($\mu' < \mu$). We record these results in:

Corollary 2 *An economy with $\mu < -\frac{\delta_0}{\delta_1}$, which approaches the brown steady state, could raise its (utilitarian) welfare by having a green transition. A higher value of λ relative to ζ widens the range of μ for which the economy is in such a trap.*

The possibility of a trap is perhaps not so surprising given that firms maximize profits rather than social surplus. Rather what makes the result interesting is the possibility to escape the trap through cultural change, even in the absence of collective action.

A frequent reaction to Corollary 2 would be to point out that a social planner could increase welfare by committing to a policy path that fought emissions. However, in our view that trivializes the policy challenge. Instead, we explore different dimensions of democratic politics, asking whether the dynamic market failure in our baseline model will be addressed by a sequence of policymakers who cannot commit to future policies.

4 Policy and Politics

We now introduce policies that may address the pollution problem. These policies are determined in a political equilibrium where citizens may use their voting rights and firms may pay campaign contributions. As discussed in Section 2, much of the existing literature either looks at exogenous policy or focuses on the policy choices by a social planner, who maximizes a given objective function under full commitment. But real-world politicians who hold office – or vie for it – cannot commit to future policies, as these might be reset by policymakers elected in the future. Moreover, influence activities such as lobbying may also help affect policymaking.

Policy instruments Suppose the government can set current production taxes (or subsidies) on green and brown goods, denoted by $\{t, T\}$. Like classic Pigouvian taxes, these can be used to curb externalities created by brown-goods production, alongside correcting distortions created by monopoly pricing.

Since taxes are levied on producers, they enter markups and result in prices $P = (\chi + T) / (1 - \sigma)$ and $p = (\chi + \zeta + t) / (1 - \sigma)$. Tax revenues are

$$t\gamma \left[\mu(1+g) + (1-\mu)\right] \kappa \left(\zeta + t\right)^{1-\sigma} + T(1-\gamma) \left[\mu(1-g) + (1-\mu)\right] \kappa \left(T\right)^{1-\sigma} . \tag{20}$$

These are distributed back to consumers in lump-sum fashion (independent of their type). Together with the differential consumption baskets, this means that differential taxation on green and brown goods does affect the distribution of welfare between green and brown consumers.

In terms of model parameters and tax rates, we can write the utility of a type-Γ consumer as:

$$\begin{aligned} W(t,T,\Gamma,\gamma) &= \gamma\left[\Gamma(1+g)^{\sigma}+(1-\Gamma)\right]\kappa(\zeta+t)+ \\ &\quad (1-\gamma)\left[\Gamma(1-g)^{\sigma}+(1-\Gamma)\right]\kappa(T) \\ &\quad -(1-\gamma)\lambda(1-\mu g)\kappa(T)^{1-\sigma}. \end{aligned} \tag{21}$$

4.1 Static Effects of Politics

In a democracy, social change reflects a combination of market forces and political forces in a rules-based political system. In this section, we consider two political forces: electoral competition by parties and lobbying by firms. We aim to show how each of these helps shape equilibrium policy and therefore the market incentives to produce, consume, socialize, and choose technologies. In the same manner as in Section 3, we begin by analyzing a static model. As we will see, the results there will continue to hold when we proceed to a fully dynamic analysis.

Electioneering Following Besley and Persson (2019), we study two-party competition around pollution policy in a setting with probabilistic voting (Lindbeck and Weibull 1987, Persson and Tabellini 2000).[7] We label the two (given) parties $D = A, B$ and assume these are solely motivated by winning elections. Each party D proposes a tax platform for the current period: $\left\{t^D, T^D\right\}$. Voters are of two kinds. Swing voters cast their ballots based on proposed policy platforms and loyal voters cast their ballots for one party independent of policy. Our model has the same proportion of swing voters among green and brown consumers.[8]

Swing voters are subject to idiosyncratic and aggregate popularity shocks and parties maximize their expected payoffs knowing the distributions (but not the realizations) of these shocks. In the Appendix, we study equilibrium policy choices. We look for a Nash equilibrium in platforms and show that each party acts "as if" it maximizes a *static* Utilitarian social-welfare function based on the current-period utilities of those presently alive. In the next

[7] We pick this particular formulation for pure convenience. As discussed in Besley and Persson (2019), other political models would yield similar conclusions.

[8] The model could be expanded to incorporate parties with ideological differences with a correlation between green preferences and ideology, as suggested in the evidence (Anderson et al 2019).

subsection, we show that this is also the appropriate party objectives in a dynamic model without commitment.

Proposition 2 *In an equilibrium with electoral competition, parties converge on taxes:*

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

Equilibrium taxes play two roles. They correct the damages from brown-sector pollution (the term in $(1-\sigma)$). And they offset the distortion from monopoly pricing (the terms in $-\sigma$). As a result, the green tax is negative – i.e., a subsidy. Note that $\chi+\lambda$ is the social marginal cost of a brown good, while $\chi+\zeta$ is the social marginal cost of a green good.

If these costs are constant over time – as we assume in this section – so are equilibrium taxes. In particular, as long as green and brown citizens face the same pollution costs, the share of green consumers does not directly affect equilibrium policy. In the next section, we consider an extension where green consumers care more about pollution than brown consumers.

Lobbying To model lobbying in a simple way, we follow Baron (1994), supposing that opportunistic parties not only internalize voting preferences of voters, but also prospective (endogenous) contributions of lobbying firms that can help them win elections. If one set of firms (green or brown) is better organized than the other, then it is favored by the policy process.

Assume a share ϕ of all green firms belong to a coalition that interacts with political parties. Each participating firm pays a campaign contribution c^P to party D at cost $\frac{1}{2}(c^D)^2$. Similarly, a share Φ of all brown firms make contributions C^D at cost $\frac{1}{2}(C^D)^2$. Aggregate contributions raise party D's probability of winning, in proportion to parameter ξ. Firm coalitions decide on contributions after parties have designed their policy platforms, but before the election. To keep things simple, the "organized" shares ϕ and Φ are given, also in the dynamic analysis to follow

The Appendix shows that this election *cum* lobbying model implies:

Proposition 3 *In an equilibrium with electoral competition and lobbying, parties converge on taxes:*

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

These taxes coincide with those in Proposition 2 when either $\xi = 0$ – money is ineffective in politics – or $\Phi = \phi = 0$ – no firms are organized to lobby. As ξ increases, the green-goods subsidy rises and the brown-goods tax falls. However, this strikes differently across green and brown sectors if Φ and ϕ differ – i.e., lobbying organization is asymmetric. If brown firms are better organized ($\Phi > \phi$), this cuts T relative to t.[9]

The power of endogenous policy The overall impact of policy, with or without lobbying, hinges on how it affects the pricing and profitability of green and brown goods. In particular, the taxes in Proposition 2 make firms internalize social surplus rather than profit – thus they price green goods at marginal cost, $\zeta + \chi$. Similarly, brown goods are priced at (static) social marginal cost $\lambda + \chi$, which adds in the marginal externality cost.

If $\lambda > \zeta$, consumers face lower prices of green goods than of brown goods, the flipside of pricing under laissez faire. Moreover, green profits are higher, raising the incentive for firms to go green. In the next subsection, we show that this affects not just the economy's static resource allocation, but also its dynamic path.

However, lobbying can undermine these effects and restore higher prices and lower profitability of green goods. To see this consider Proposition 3, in the case when the green sector is not organized – i.e., $\phi = 0$. Then, the marginal costs faced by green firms are proportional to $\chi + \zeta$, while those of brown firms are proportional to $\lambda + \chi/(1 + \Phi\xi\,(1 - \sigma)\,\sigma)$. Now, if $\Phi\xi$ is sufficiently high – i.e., brown firms are well organized or money matters in politics – brown production is favored in the same way as in laissez faire.

4.2 Dynamic Consequences of Politics

Let us study dynamics when policy is set in a political equilibrium. Each period, s, now has five stages, where the new (political) stage 2 is divided into the three sub-stages modeled above:

1. Given shares of green consumers μ and green firms γ enter the period

[9] The effect of lobbying is to lower the prices for both goods to

$$p = \frac{\chi + \zeta}{(1 + \xi\phi\,(1 - \sigma))} \text{ and } P = \frac{\chi + \lambda}{(1 + \Phi\xi\,(1 - \sigma))}.$$

This will benefit brown firms disproprtionately if $\Phi > \phi$.

2. (a) Parties announce electoral platforms $\{t, T\}$; (b) lobbying firms offer contributions to parties; (c) an election outcome is realized subject to idiosyncratic and aggregate shocks

3. Price-setting, production and consumption decisions take place

4. Technology adoption among producers determines γ'

5. Socialization among consumers determines μ'.

Dynamic voter and party objectives Even though we study politics in a dynamic setting, the static political equilibrium model from the previous subsection still applies even if all actors are forward-looking. The culprit here is the lack of commitment, a natural assumption in a political context. The only way that politics helps shape the dynamic path is that citizens anticipate *future* (politically determined) policy. We now develop this argument in greater detail.

Consider the socialization model that we used under laissez faire.[10] A (biological or cultural) parent-voter of identity type $\Gamma \in \{0, 1\}$ in period s cares about the utility of her offspring in the next generation. Her *expected* utility, given (21), includes the (again undiscounted, for simplicity) expected utility of her offspring, which includes the expected utility of the offspring's offspring, and so on:

$$\begin{aligned} E\sum_{\varepsilon=0}^{\varepsilon=\infty} W_{s+\varepsilon} &= W(\Gamma, t, T, \gamma) + EW(\Gamma', t', T', \gamma(\mu', t', T')) \\ &\quad + E\sum_{\varepsilon=2}^{\varepsilon=\infty} \left\{ W\left(\Gamma_{s+\varepsilon}, t_{s+\varepsilon}, T_{s+\varepsilon}, \gamma\left(\mu_{s+\varepsilon}, t_{s+\varepsilon}, T_{s+\varepsilon}\right)\right)\right\}. \end{aligned} \tag{22}$$

This parent-voter would like parties to pick policies that raise her children's payoff, namely $EW(\Gamma', t', T', \gamma(\mu', t', T'))$, the second term on the right-hand side of (22), and even the continuation utility defined over more distant future payoffs in the third term.[11]

Since consumers and producers are atomistic, they (rationally) ignore the effect of their actions on current and future aggregate outcomes such as

[10] The underpinning microfoundations are spelled out in Section A.1 of the Appendix.

[11] Note that we are abstracting from discounting, which is not essential for the argument, but could easily be added.

μ', γ', or policies such as t', T'. While political parties are able to internalize any future effect of their current decisions, they have no way of influencing $\{\mu', t', T'\}$, which determine next period's payoffs. First, they cannot commit policymakers elected in the next period to a particular policy $\{t', T'\}$. Second, they cannot use current taxes $\{t, T\}$ – which they do control – to alter $\{\mu', t', T'\}$ indirectly. As individual firms and households, parties must thus take next period's green share and policies $\{\mu', t', T'\}$ as given. A similar argument applies to all future periods, $s+2, s+3$, ...

Thus the no-commitment assumption has real bite. Specifically, the best a party can do is to focus on garnering votes from today's swing voters (or lobbying contributions from firms) by setting $\{t, T\}$ to affect their current payoff, the first term on the right-hand side of (22). Thus, the static policy outcomes derived in Section 4.1 are also the political equilibrium in the dynamic model.

Value socialization among consumers The analysis of socialization in the laissez-faire economy continues to apply, so the dynamics for the green share in (6) still holds. However, we must modify the expression for Δ' in (7) due to the presence of taxes to yield:

$$\Delta' = \widehat{\delta}(\gamma') = \frac{\sigma g}{1-\sigma}\left[\gamma' \kappa(\zeta + t') - (1-\gamma')\kappa(T')\right], \tag{23}$$

where the equilibrium taxes, $\{t', T'\}$, are as stated in Propositions 2 and 3.

Technology adoption among firms Profits also depend on taxes and are given by $\Pi(T, \mu) = \sigma\kappa(T)[1-\mu g] - S[mi]$ and $\pi(t, \mu) = \sigma\kappa(\zeta + t)[1+\mu g] - S[mi]$. Thus (9), the expression for the fraction of green firms, is replaced by:

$$\gamma' = \hat{\gamma}(\mu') = \max\left\{0, \sigma \frac{\kappa(\zeta + t')[1+\mu' g] - \kappa(T')[1-\mu' g]}{m}\right\}. \tag{24}$$

It is straightforward to see that the share of green firms is higher with endogenous taxes than under laissez-faire, as long as $T' > 0 > t'$. Because κ is decreasing, the green-goods share γ' is positive even with a zero share of green consumers $\mu' = 0$, as long as $\zeta + t' < T'$, there is a sufficient tax inducement to go green.

Combining socialization and technology choices Substituting $\hat{\gamma}(\mu')$ into (23), we can rewrite the basic result in (12) as follows:

$$\Delta' = \delta(\mu') = \max\left\{-\frac{\sigma g \kappa(T')}{1-\sigma}, \widehat{\delta}_0 + \widehat{\delta}_1 \mu'\right\},$$

where

$$\widehat{\delta}_0 = \frac{\sigma g}{1-\sigma}\left[\frac{\sigma[\kappa(\zeta+t')^2 - \kappa(T')^2]}{m} - \kappa(T')\right], \tag{25}$$

which unlike (13) need not be negative; indeed, $\widehat{\delta}_0$ is positive if $T' - (\zeta + t')$ is positive and large enough. The counterpart to the slope coefficient (14) is:

$$\widehat{\delta}_1 = \frac{\sigma^2 g^2}{1-\sigma}\frac{[\kappa(\zeta+t') + \kappa(T')]^2}{m} > 0 \tag{26}$$

which is positive like δ_1.[12]

The key difference with laissez fair is that $\widehat{\delta}_0$ and $\widehat{\delta}_1$ now depend on policy. However, since t' and T' are independent of μ – something we relax in the next section – they are constant over time. In fact, it is easy to see that the laissez-faire coefficients (13) and (14) are special cases of $\widehat{\delta}_0$ and $\widehat{\delta}_1$ when $t' = T' = 0$. Changes in $\widehat{\delta}_0$ and $\widehat{\delta}_1$ become sufficient statistics for the dynamics of values characterized by the function $\delta(\mu')$.

Politics and dynamics The following is the counterpart to Proposition 1:

Proposition 4 *If $\widehat{\delta}_0 + \widehat{\delta}_1 > 0$, a society with endogenous policy always converges to a green steady state if $\widehat{\delta}_0 > 0$, a sufficient condition for which is that $T - (\zeta + t)$ is positive and large enough. If $\widehat{\delta}_0 < 0$, it converges to a green steady state iff green values are large enough that $\mu \geq \widehat{\mu} = -\widehat{\delta}_0/\widehat{\delta}_1 > 0$.*

Now, society can converge to a green steady state from any initial green share. This happens when $\widehat{\delta}_0 > 0$, $\delta(\mu') > 0$ for all values of μ'. The sufficient condition in the proposition follows from the definition of $\widehat{\delta}_0$ in (25). In words, a high enough equilibrium brown tax can ensure a green transition even if the share of green consumers is small (or zero). If this condition does not

[12] As above, we assume that $\varkappa$ is small enough such that $\widehat{\delta}_1 \varkappa < 1$.

hold, the green transition requires a large enough share of green consumers, but the critical share is generally lower than under laissez faire.[13]

By Proposition 4, we can thus have the same kind of dynamics as in Proposition 1 and illustrated in Figure 1, namely convergence to a brown or a green steady state depending on the initial share of green values. But we can also get a green transition for any initial share. We illustrate the latter situation in Figure 2.

Insert Figure 2 about here

However, Proposition 4 states the condition for a green transition in terms of tax rates t' and T',which are themselves endogenous (albeit constant). We now exploit the earlier results in Proposition 2 and 3 to state how the dynamics are influenced by the more basic parameters of the model.

Electoral competition and dynamics Suppose first that equilibrium tax rates are determined solely by electoral competition in each period. Proposition 2 highlighted the role of λ and the gap in private marginal costs between brown and green production ζ. Combining these results with the results in Proposition 4, we have:

Corollary 3 *If the brown-goods pollution externality λ is high enough relative to higher costs of producing green-goods, ζ, there is a green transition from any initial share of green values μ. When there are multiple steady states, then a higher difference $\lambda - \zeta$ shifts down the critical value, $\hat{\mu}$, above which a green transition occurs and therefore widens the range of parameter values for which a green transition is ensured.*

This corollary highlights the key role of politics in making policy sensitive to externalities created by the market. The role of $\lambda - \zeta$ makes intuitive sense because $\lambda + \chi$ measures the social marginal cost of producing brown goods, while $\zeta + \chi$ measures the social and private marginal cost of producing green goods. Even though politicians only internalize the short-run (current-period) effect of externalities, people still expect next-period politicians to

[13] There are three possible cases for $\widehat{\delta}_0$. In the first, $\widehat{\delta}_0 > 0$, as highlighted in Proposition 4. In the second, $-\frac{\sigma g \kappa(T')}{1-\sigma} < \widehat{\delta}_0 < 0$. Then, $\gamma' > 0$ even if $\mu' = 0$ and $\delta(\mu)$ is everywhere increasing. In the third, $\widehat{\delta}_0 < -\frac{\sigma g \kappa(T')}{1-\sigma}$ and $\gamma' = 0$ if $\mu' = 0$. Then, $\delta(\mu)$ has a linear segment for low μ' as in Figure 1.

implement higher taxes on brown firms if the externality is larger. This induces more firms and consumers to go green, even though today's politics cannot affect future outcomes or commit to a future policy desired by a welfare-maximizing social planner.

Corollary 3 is a limited cause for optimism, although it offers no guarantee of a green transition and the economy can still be caught in the kind of trap discussed in Subsection 3.2 above.

An example of policy failure Policy in our model has to be time-consistent. In the laissez-faire economy, there were good reasons to think that the failure of firms and consumers to respond to externalities could lead to sub-optimal outcomes. While it may move allocations in a favorable direction, it is clear that politics, without commitment, does not necessarily rectify this situation.

To make this concrete, consider a case where everyone correctly anticipates that from some future period S, the pollution cost will be considerably higher than today, say at $\lambda_S >> \lambda$. Without commitment to future taxation, current policy will maintain a low tax gap $T' - t'$. With a low initial share of green consumers and a relatively high adoption cost m, $\mu < \widehat{\mu}$. As a consequence, the share of green consumers (and with it the share of green firms) falls towards the brown steady state.

When λ eventually rises in period S, the critical juncture falls to $\widehat{\mu}_S < \widehat{\mu}$. But by then, the share of green consumers may have fallen far enough that $\mu_S < \widehat{\mu}_S$. Therefore, society continues its path towards a brown steady state. This happens even if the externality is so high that the initial share of green consumers was high enough to exceed the new critical juncture for a green transition – that is, $\widehat{\mu}_S < \mu < \widehat{\mu}$.

Lobbying and dynamics Next, we allow equilibrium tax rates to also reflect lobbying. Proposition 3 says that the tax on brown (green) goods T' (t') is decreasing in the share of brown (green) firms Φ (ϕ) that belong to the lobbying coalition. Moreover, this dampening effect is larger the higher is ξ, the clout of money in politics. Using these results, the expressions for (25) and (26) and Proposition 4 imply:

Corollary 4 *A larger (positive) gap between the extent to which brown and green firms are organized, $\Phi - \phi$, makes it less likely that a green transition occurs, increasing the critical juncture, $\hat{\mu}$, for which a transition* *occurs. This effect is stronger* $\Phi - \phi$ *when money matters more in politics – i.e.,* ξ *is higher.*

These results are driven by the impact on equilibrium policy in the same way as the results in Corollary 3. But, Corollary 4 carries a more pessimistic message about political equilibrium outcomes. If brown firms are powerful enough in lobbying relative to green firms – and if money matters enough in politics – then electoral competition *cum* lobbying shrinks the brown-green profitability gap towards its value under laissez faire.

Policy failure redux Suppose that $\Phi \to 1$, $\phi \to 0$, and $\xi \to \infty$ in Proposition 3. Then, we get $t \to -\sigma(\chi + \zeta)$ and $T \to -\sigma\chi$. That is, in the limit, equilibrium taxes only offset monopoly power, but do nothing about the brown-sector pollution externality. This negative result starkly illustrates the kind of policy pessimism emphasized by climate activists when they point to the harmful influence of powerfully organized fossil-fuel industries.

5 Dynamic Politics

The previous section illustrates how the forces of equilibrium politics may shape static resource allocation as well as dynamic paths in the presence of pollution externalities. But the policy dynamics do not interact with values and technologies over time. We now enrich the model in three directions, all of which introduce truly dynamic aspects of politics.

In the first subsection, we assume that citizens with green values place a higher weight on pollution. In this setting, policy responds to the share of green citizens μ, and politics plays an integrated role in the dynamics.

The second subsection formulates a simple framework with individual political activism, which works as a (partial) substitute for state action. These private politics, too, as well as the resulting party politics, respond the green-citizen share.

In the third subsection, we expand the policy menu with publicly funded grants for adopting a green technology. This introduces strategic, forward-looking motives in policymaking, because that policy – unlike current taxes t and T – can influence future green shares, γ' and μ'.

5.1 Political Multipliers

This subsection develops an extension of the model with policy and electoral competition where policy endogenous to the green share μ.

Increased salience of pollution Suppose green consumers have stronger concerns about pollution with θ being an additional weight on pollution:

$$\frac{1}{1-\sigma}\left[\int_0^{\gamma}(1+g)^{\sigma}y(i)^{1-\sigma}di+\int_{\gamma}^{1}(1-g)^{\sigma}Y(i)^{1-\sigma}di\right]+x-(\lambda+\theta)\bar{Y}. \quad (27)$$

A higher value of θ corresponds to higher salience of pollution costs. This could also reflect a stronger sense of collective – not just individual – identity among green consumers. Such a collective identity can be fostered if a social movement is formed by members of that group as in Besley and Persson (2022).

Implications for static policy This yields the following modified version of Proposition 2 to:

Proposition 2′ *In a political equilibrium without lobbying, where green citizens have added pollution salience of θ, and make up a fraction μ of the population, both parties choose the same taxes equal to*:

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

As before, the corrective tax on polluting goods reflects a weighted group average of the perceived pollution costs. Note, however, that the tax on brown goods will be higher by a factor $\mu\theta$, reflecting the additional salience of pollution and the proportion of green consumers. The price of brown goods will now rise over time if μ does.

Implications for the dynamics The dynamics will now incorporate a new feedback effect which we refer to as a "political multiplier" since it reflects a complementarity between more green consumers and higher brown-goods taxes which, in turn, makes it even more attractive to become a green consumer.

The implications are straightforward to analyze, once the new $\{T', t'\}$ are plugged into (23). The political multiplier affects the speed of a green transition and whether it occurs at all. Now $\widehat{\delta}_0$, defined in equation (25), is increasing in μ. In terms of Figure 2, the intercept of the $\widehat{\delta}_0 + \widehat{\delta}_1\mu$ curve gradually shifts upwards (downwards) in every period, on a path where the green consumer share μ is growing (shrinking). Clearly, this will speed up the transition towards the green (brown) steady state.[14]

More intense rhetoric among green citizens can persuade them to vote for parties that offer more stringent environmental policies. Even as a minority, the green can get disproportionate attention and push up taxes on brown goods, which can help break a trap around a brown steady state. Of course, things can go the other way if brown (materialist) consumers get upset – as when *gilets jaunes* protests made French President Macron back off from a proposed hike of gasoline taxes. Adding a salience effect highlights the long-run dynamic effects of such phenomena and shows how preference intensity can help shape policy dynamics.

5.2 Private Political Activism

We now expand the framework to include private political activism affecting brown and green firms – a form of "private politics" in the sense of Baron (2003).

Private political action Individual actions against polluting firms are an important real-world example of private politics (see Abito et al. 2019 for a review) and activists could either harass or promote firms directly – outside of the regular political process – in a fashion that alters production costs and hence profits. These cost effects will, in turn, affect dynamic incentives.

We could model such activism in different ways, with more or less sophisticated private behavior. To keep things simple, we follow Passarelli and Tabellini (2017) who model protests as a purely emotional response – i.e., group members get a psychological reward by joining others in a public display of aggrievement or frustration. We imagine that such emotional responses by green consumers are positive in the case of green firms and negative in the case of brown firms. The seems like the kind of activism that leads protestors in organizations like Extinction Rebellion to target certain kinds of firms such as fossil-fuel producers and distributors.

[14]Note that while $\widehat{\delta}_1$, defined in (26), is decreasing in μ, the Appendix confirms that $\delta(\mu')$ is still increasing.

Negative emotional activism deters brown production. Among many examples, resource-intensive companies fear organizations like the Rainforest Action Network.[15] This network pressures brown firms outside the standard political process, by sit-ins, product boycotts, or campaigns, where green activists threaten brown firms to lower their emissions.[16] We suppose that disruptive action is proportional to the share of green consumers and pushes up the marginal cost of a typical brown firms to $\chi + \mu d(\lambda)$, where $d(\lambda) > 0$ denotes "disruption" and is increasing in λ. We thus take a reduced-form approach where such activity increases in the green consumer share and in the costs of pollution. But we could easily endogenize the incentives to engage in protest.

Positive emotional activism instead promotes green production. A good example is Greenhouse PR, which not just coordinates actions against brown firms, but promotes green products – e.g., via GRIDSERVE, a new UK network for electric-vehicle charging. We model positive and negative activism in parallel ways with positive activities being proportional to the green-consumer share, thereby lowering the marginal cost of producing green goods to $\chi + \zeta - \mu a(\lambda)$. Here, $a(\lambda)$ stands for "advertising," an increasing function of λ.[17] This raises the consumption of green goods and the profitability of green firms, all else equal.

Static implications of activism Private activism directly cuts (raises) current profits and production of brown (green) goods. But, in a model of endogenous policies, it also affects politically optimal tax rates as follows:

Proposition 2″ *In an equilibrium with electoral competition and political activism, both parties choose taxes:*

$$T = (1-\sigma)\lambda - \sigma(\chi + \mu d(\lambda)) \quad \textit{and} \quad t = -\sigma(\chi + \zeta - \mu a(\lambda)).$$

Private politics affects policy platforms, since it alters the marginal production costs in green and brown firms. This is offset in tax policy – i.e.,

[15] See https://www.ran.org/.

[16] Bezin (2015) proposes a model of cultural evolution for environmental preferences based on private contributions to environmental protection.

[17] This is to maintain the parallel with disruptive action. But both kinds of activities could also be thought of ways of trying to convince people that the quality of brown goods is inherently lower and that of green goods inherently higher.

private action crowds out public action. For example, negative activism *lowers* brown-goods taxes although this crowding out is less than one-for-one and the net marginal cost of brown goods is higher with negative climate activism. To see this, note that the social marginal cost of producing brown goods is now $\chi + \lambda + \mu d(\lambda)$.

Likewise, positive activism generates a policy reaction from parties. The direct cut in the marginal cost of green goods is thus partially offset by a lower public subsidy, but the end result is still a lower net marginal cost. In either case, private politics affects the relative welfare of green and brown consumers, inducing a higher or lower overall price of each type of good.

Dynamic implications of activism Political activism also affects dynamics with details of the analysis in the appendix. Overall, it has similar consequences to increasing T' and reducing t' over time. Moreover, this varies with μ analogously to the political multiplier discussed in the previous subsection. Because $\widehat{\delta}_0$, defined in equation (25) and $\widehat{\delta}_1$, depend on μ via equilibrium taxes the $\widehat{\delta}_0 + \widehat{\delta}_1\mu$ curve shifts over time. Specifically, the relative fitness of green values Δ' – and thus the growth of green consumers – gradually shifts up (down) on a path where the green share is growing (shrinking).

We summarize the overall impact in:

Corollary 5 *Compared to the outcomes under electoral competition (only), more forceful activism of either kind – i.e., higher values of $d(\lambda)$ and $a(\lambda)$ – widens the range of initial green shares for which there is a green transition. A higher value $d(\lambda)+ a(\lambda)$* also *shifts down critical value $\hat{\mu}$ for green values at which a green transition is ensured. If a green transition occurs, the adjustment towards the green steady state is more rapid.*

Intuitively, political activism introduces an additional feedback effect in the dynamics. A higher (expected) share of green consumers not only raises the relative (expected) profitability of green production via the market-share effect, but also via more support to green firms and more costly protests towards brown firms. This "private-politics multiplier" further speeds up the share of brown producers that go green and thereby the socialization of consumers.

An interesting feature of the model with private politics is what happens as μ increases, where Corollary 5 predicts that disincentives to brown firms become stronger over time. This is true even if with higher μ, the externality from brown production is getting smaller. As μ gets close to one, private politics ensures that brown production is less profitable, speeding up the transition to a green economy.

5.3 Strategic Policy

In this subsection, we expand the set of available policy instruments with subsidies to producers who are going green.

A subsidy for green technology adoption Specifically, suppose that government can offer a flat (lump-sum) grant of r to those firms that turn from brown to green. The Green Deal recently announced by the EU is an example in point, as it offers the possibility of giving grants to firms that switch to new cleaner technologies.

Formally, in terms of the within-period timing, the grant is paid out just before stage 4 to the firms that make the switch. The cost of the grants is borne in equal amounts by all consumers.

Adding a grant for going green implies that the fraction of green firms, instead of (24), will be

$$\hat{\gamma}(\mu', r) = \max\left\{0, \frac{\sigma(\kappa(\zeta + t')[1 + \mu' g] - \kappa(T')[1 - \mu' g]) + r}{m}\right\}, \tag{28}$$

where we have spelled out the dependence on r.

In addition to these direct incentive effects, the technology grants will indirectly affect the future share of green consumers. We can say that the grants have a "cultural effect." To be more precise, we can use (23) to write

$$\hat{\mu}'(r) = \begin{cases} \frac{\mu\left[1+\varkappa\left(\widehat{\delta}_0+\frac{r}{m}\right)\right]}{1-\varkappa\widehat{\delta}_1\mu} & \text{if } \widehat{\delta}_0 + \frac{r}{m} + \widehat{\delta}_1\mu'(r) > -\frac{\sigma g\kappa(T')}{1-\sigma} \\ \mu\left[1 - \varkappa\frac{\sigma g\kappa(T')}{1-\sigma}\right] & \text{otherwise.} \end{cases} \tag{29}$$

Whenever the share of green firms is positive, $\hat{\gamma}(\mu', r) > 0$, both $\hat{\mu}'(r)$ and $\hat{\gamma}(\mu', r)$ are increasing in r.

Optimal technology grants Again, we study an economy with electoral competition, but without lobbying. Then, the levels of $\{t', T'\}$ remain the same (constants), so the grant system strictly increases the incentives to go green. Therefore, we can use (21) to define an optimal grants policy as the value of r that maximizes

$$W\left(t', T', \hat{\mu}'(r), \hat{\gamma}\left(\hat{\mu}'(r), r\right)\right) - r\hat{\gamma}\left(\hat{\mu}'(r), r\right). \tag{30}$$

In words, an optimal grant has to weigh future benefits (the first term) against current costs (the second term).

Sources of ambiguity Pinning down the optimal value of r is not straightforward, though. One effect of a higher r is unambiguously positive. To see this, write the size of the future externality $\Lambda = \lambda \overline{Y}'$ as a function of grant r

$$\Lambda(r) = \lambda\left(1 - \hat{\gamma}'\left(\hat{\mu}'(r), r\right)\right)\left(1 - \hat{\mu}'(r)\, g\right)\kappa\left(T'\right)^{1-\sigma}. \tag{31}$$

Since both $\hat{\gamma}'$ and $\hat{\mu}'$ are increasing in r, $\Lambda(r)$ must be a decreasing function. Because green and brown consumers equally value a decrease in pollution, this pollution effect of a higher r will always raise future expected welfare.

However, this is not the only effect of a higher r. The higher share of green goods will increase utility of green consumers, but decrease utility of brown consumers, which generates a conflict of interests. In addition, a higher r raises the share of green consumers, which affects utility weights. The overall welfare consequences of these additional effects are inherently ambiguous in sign.[18] If $\hat{\mu}'(r)$ is low, the two additional effects are more likely negative, which weakens the case for subsidizing adoption of the green technology. However, for high $\hat{\mu}'(r)$, the opposite is the case.

Since $\{t', T'\}$ are independent of γ', and hence of r, adding the possibility of giving grants for going green can only increase the probability of a green transition whenever $r > 0$. It could thus be an important additional instrument in the policy toolkit beyond the standard Pigouvian instruments.

[18] The direct benefit of green grants is

$$\begin{aligned}\frac{\partial W\left(t', T', \hat{\mu}'(r), \hat{\gamma}\left(\hat{\mu}'(r), r\right)\right)}{\partial r} &= \left[\left[\mu'(1+g)^{\sigma} + \left(1-\mu'\right)\right]\kappa\left(\zeta + t'\right) - \left[\mu'(1-g)^{\sigma} + \left(1-\mu'\right)\right]\kappa\left(T'\right)\right]\frac{d\hat{\gamma}\left(\hat{\mu}'(r), r\right)}{dr} \\ &+ \left[\gamma'\left[(1+g)^{\sigma} - 1\right]\kappa\left(\zeta + t'\right) - \left(1-\gamma'\right)\left[(1-g)^{\sigma} - 1\right]\kappa\left(T'\right)\right]\frac{\partial\hat{\mu}'(r)}{\partial r} - \frac{\partial\hat{E}(r)}{\partial r}\end{aligned}$$

5.4 Bottom Line

Our baseline policy model in Section 4 had no direct interdependence between value changes and policies. All three extensions in this section create such intertemporal linkages: the political multiplier based on salience acts directly on the tax on brown goods; private activism acts as an indirect tax or subsidy on the production of brown and green firms; and the technology grants are more attractive to offer with a larger anticipated share of green consumers.

In all three cases, policy or activism feeds back onto the dynamic path of values. Thus, they show how – once the appropriate threshold is crossed – policy can help a green transition gain more momentum. However, a trap where a green transition does not occur still remains as a possibility, even with such dynamic policy feedbacks. In that sense, endogenously determined policy continues to be more of a facilitator than a fundamental driver of a green transition.

6 Innovation

The baseline model has no innovations in green (or brown) technology. But it indirectly illustrates how such innovation can support a green transition if it lowers m, the cost to firms of using green technologies. In this section, we extend the model so as to turn this parameter into an endogenous variable that reflects innovation by (a collection of) technology firms. This links to the general literature on endogenous technological change (Romer 1990, Aghion and Howitt 1992), as well as the specific literature on innovation in green and brown technologies (Acemoglu et al. 2012, 2016, Aghion et al. 2016).

Green technology costs We suppose that a collection of technology firms, indexed by $k = 1, ..., K$, build the technologies needed to produce green final goods. Let q_k be firm k's marginal cost to produce a unit of that technology. Ignore capacity constraints and let $\underline{q} = \min \{q_k\}$ denote the minimum cost across technology firms.

Any one of these firms can imitate the best practice from the previous period. Alternatively, they can try to improve on it. As in the standard quality-ladders model (Grossman and Helpman 1981), improvements come in given steps Q. Firm k can spend more effort e_k on innovation, which proportionately raises the probability of a successful innovation to become the technology leader with the lowest cost of producing the green technology. Formally,

$$q_k = \begin{cases} \underline{q} - Q & \text{with probability } e_k \in [0,1] \\ \underline{q} & \text{otherwise.} \end{cases}$$

Finally, we assume that e_k has a quadratic (utility) cost.

Timing The timing is now

1. Given shares of green consumers μ and green firms γ enter the period
2. (a) Parties announce electoral platforms $\{t, T\}$; (b) lobbyists offer contributions; (c) an election outcome is realized subject to idiosyncratic and aggregate shocks
3. Price-setting, production and consumption decisions take place
4. Producers of green technologies choose their innovation effort $\{e_k\}_{k=1}^{K}$, which determine their $\{q_k\}_{k=1}^{K}$
5. Technology adoption among producers – at a fee m, which is set in Bertrand competition among green-technology producers – determines γ'
6. Socialization among consumers determines μ'.

Much of the analysis carries directly over from the baseline model with taxation. Thus, we focus on the new dimensions at stages 4 and 5 (in reverse order).

Price setting by technology firms At stage 5, technology firms engage in Bertrand competition in the pricing of green technology to final-goods firms. Specifically, suppose that ι is the number of firms that managed to innovate at stage 4. Then, we have

$$m = \begin{cases} \underline{q} & \text{if } \iota \leq 1 \\ \underline{q} - Q & \text{otherwise.} \end{cases}$$

With either one or zero innovators, the fee for the green technology is set at $m = \underline{q}$. If nobody managed to innovate, all firms have the same cost and set the price the common minimum cost. With one innovator, that firm has a one-period monopoly. So it can set its fee at $\underline{q}$, take over the whole market and earn a profit of Q per firm that purchases the right to use the green technology. If two or more firms have reduced the cost to $\underline{q} - Q$, Bertrand competition implies that these firms bid down their profits to zero and set $m = q - Q$.

Given the optimally set fee, final-goods firms face exactly the same problem as in the baseline model. Thus, they pay a license fee m for using the green technology in the next period, given that the future expected profits from doing so are large enough. As before, this determines the future share of green firms γ' from condition (24).

Equilibrium effort in innovation Let us finally consider innovation decisions at stage 4. The monopoly profit if one and only one firm manages to innovate is $Q\gamma'$ where Q is the profit per firm and γ' is the extent of the market. The innovation decisions are thus the outcomes of a Nash equilibrium, where

$$e_k = \arg\max \left\{ e \left[\prod_{l \neq k} (1 - e_l) \right] \gamma' Q - \frac{1}{2} (e)^2 \right\}.$$

In a symmetric equilibrium for all k, the optimal effort *cum* innovation rate solves

$$\hat{e}(\gamma' Q) = (1 - \hat{e}(\gamma' Q))^{k-1} \gamma' Q. \tag{32}$$

It is straightforward to check that optimal effort $\hat{e}$ is increasing in γ' and Q. This makes sense, as effort raises the likelihood of being a sole innovator and reaping a prize of $Q\gamma'$. As mentioned above, the marginal final-goods firm is still determined by (24). To close the model, we observe that

$$\gamma' = \frac{\sigma (\mu' g [\kappa(\zeta + t') + \kappa (T')] + [\kappa(\zeta + t') - \kappa (T')])}{\underline{q}}. \tag{33}$$

Consequences of adding innovation Innovation can influence whether a green transition takes place. Successful innovation drives down m over time. However, any decrease in m materializes with a one-period lag if $\iota = 1$ – i.e., when there is a monopoly innovator who can exploit that position for one period. When m falls, the share of green firms grows over time which increases the fitness of being green, Δ', and drives up the share of green consumers μ'. A fall in m thus increases the likelihood of a green transition for any given policy $\{t, T\}$.

Production taxes now have an additional effect since they can boost innovation in green technology. Specifically, via (33), anticipated future taxation enhances the market for green goods and hence increases γ'. This both raises the share of green consumers as in Section 4 and from (32), it will increases the likelihood of improving the green technology. This adds a new, triple complementarity between green innovation, green production and green consumption. This means that innovation will speed up a green transition, should it occur.

However, adding innovation does not eliminate the possibility of a trap in which no green transition occurs. This is a caution against blindly hoping for a technological fix to kickstart the green transition. Endogenous innovation depends on the same processes as those we have already studied: the interplay between the time varying paths of green consumers and firms, and the policy path chosen in the political process. Thus a low value of μ and modest taxation of brown goods will limit the pace of innovation. Innovation is a complement with changing culture and policy in bringing about a green transition. Without these supportive changes, technology may change too slowly.

Of course, we could also we expand the menu of policy instruments with a subsidy to innovation. Policies that directly encourage future innovation will have the standard benefits in our model, but they will also spill over on the dynamics of values in the same way as in Subsection 5.3 above.[19] Thus our model does suggest how the logic of a "moonshot" effort to invest in green technology might have a dynamic impact. This would be a like a decisive downward shift in m, a big push that could change the dynamic path of an economy. But – just like other policy interventions – a moonshot effort would have to be a politically incentive compatible policy.[20]

[19] See, for example, Besley and Persson (2022b) and Bezin (2015, 2019) for models along these lines.

[20] As stressed in Besley and Persson (2022b), an additional impetus could come from science acting as a more powerful civil society group that shifts technology.

7 Conclusions

Standard models of environmental policy omit two important elements that influence the likelihood of a green transition. The first is the role of changing values, which shift the whole indifference map rather than forcing any green adjustment to moves along fixed indifference curves. Such value changes may be essential to the idea of a green transition, but is missing from most dynamic models. We have shown that cultural change can respond to economic and policy change. The second omitted element is the role of political incentives. Enriching an economic policy framework to incorporate political feasibility lays bare the difficulties of achieving a green transition. Politics can facilitate a transition but this depends on incentives. Putting values and policies together clarifies the challenges that need to be met to create a green transition.

The paper emphasizes the interdependencies between institutions and culture. The underlying preferences and production technologies determine economic incentives for firms and consumers to go green. Institutions for cultural transmission through firms, families and social structures affect the dynamics of values, even in a laissez faire world. Problems of no-commitment and the nature of electioneering, lobbying and private activism all play an important role.

The model also highlights that the standard Coase (1960) theorem, as well as the political Coase theorem articulated by Acemoglu (2003) may both fail. In a laissez-faire world, polluters (or those subject to pollution) do not own the right to a clean environment. This problem is compounded as *future* generations have no rights to influence the behavior of current generations. Changing values adds a further layer of complication as the effect of pollution policy on the perceived welfare of the current generation is likely to be a poor guide for policy. After a green transition, welfare will be higher if λ is large enough. But to action this would require that future consumers with green preferences could influence current policy. This is a complicated economic and philosophical problem that deserves more study.

Our way of looking at political and market failure offers a fresh perspective on how democratic politics may or may not contribute to fixing dynamic social problems. Even the optimistic view of politics as maximizing the average utility of those currently alive is not always enough to put society on an optimal path. Hence, policy activism outside the political process may be a welcome distortion, that could improve both the speed and direction of change. This is a like a political theory of the second-best, where adding an apparent additional political distortion can actually improve long-run welfare.

At the present time, environmental activists and some scientists encourage governments to declare a climate emergency. In the model, we can think about an emergency as trying to convince others that λ is higher than conventionally believed. The model illustrates how this can push the dynamics in the right direction, by raising μ', if citizens anticipate a stricter future policy. However, for the path to be time consistent, citizens have to believe that others are equally convinced about the claims in a declared emergency.

One can imagine many extensions of our framework. These include more extensive mechanisms whereby evolving values may influence a green transition. One would be to allow for intrinsically motivated scientists. As in Besley and Persson (2022b), this could help speed up the adjustment towards a green steady state by making green innovation relatively cheaper. Another extension would be to allow intrinsic incentives to influence financial markets. In a richer model with a meaningful savings and investment side, value-driven propensities to invest would serve to make production or innovation in green firms cheaper than in brown firms.

Although we have included core elements of politics, we have not considered the role of endogenous changes in political organization along the lines of Besley and Persson (2022a). Social movements – as the Sierra Club and Greenpeace – have been a key feature of environmental politics. In our model, we can think about such movements as raising the salience of environmental issues, λ. Entry of green parties, a phenomenon seen in Europe since the 1970s, is also important. These new parties may tilt policies in a green direction by building coalitions with traditional parties that have been formed along traditional right-left issues, thus overcoming tendencies for traditional parties to bundle green policies with traditional economic issues.

Additional features could make our framework better suited for studying the climate challenge. We have considered the green transition of a single country in response to pollution within its own boundaries. This is certainly realistic for changing weather patterns that raise the risks of local flooding and extreme storms. It is also relevant for local responses to air pollution in many countries. But a green transition in a single country may have limited impact on *global* greenhouse-gas emissions. It could still be interesting to explore other positive spillovers, such as making new green technologies globally available or spreading green values across country borders.

Another relevant extension would be to tie the global externality to *cumulated* pollution stocks rather than to flows. These externalities could be modeled as a continuously mounting cost (Nordhaus and Boyer 2000), or as a mounting risk of a climate disaster (Acemoglu et al. 2012). In either case, one could study the conditions for escaping a climate trap in terms of the share of countries that managed to engineer a green transition (and the speed of those transitions).

More broadly, understanding the quagmire that prevents a green transition may be necessary to navigate a path around it (or out of it). Democratic politics has to find ways of facing up to large-scale dynamic policy problems, even in a world where policy commitments are infeasible. Understanding the logic of this challenge provides a useful first step in changing perceptions of the task that lies ahead.

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Appendix

A Additional Material

A.1 Socialization One way to derive (6) in Section 3.2 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 and Persson (2019).

All children have two parents and parent pairs have two children. Reproduction follows a matching process, where a fraction υ of matching is assortative – i.e., parents have the same identity. The remaining fraction $1-\upsilon$ 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.[21] However, a child with mixed parents may identify as green depending on fitness advantage Δ' – next period's expected-utility difference, not discounted, for simplicity – when the child is adult. The child's identity also depends on a family-specific shock ψ with infinite support and distribution function $F(\cdot)$,which is symmetric around a zero mean with density $f(\cdot)$. A mixed-parent child will hold green values if $\psi \leq \Delta'$, so the probability of this event is $F(\Delta')$. With a continuum of families, this is the proportion of children with green values among mixed parents. Note that $F(\cdot)$ increases smoothly in Δ with $F(0)=1/2$. This yields

$$\mu' = \mu + (1-\upsilon)\, 2\mu (1-\mu) \left[F(\Delta') - \frac{1}{2} \right]. \tag{34}$$

To interpret this expression, note that assortatively matched couples preserve the proportion of green. Among the randomly matched, a fraction μ^2 involve two green parents. The fraction of mixed-parent households is therefore $2\mu(1-\mu)$.

Let's rewrite this expression as

$$\frac{\mu' - \mu}{\mu} = (1-\upsilon)\, 2(1-\mu) \left[F(\Delta') - \frac{1}{2} \right].$$

[21] 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.

Finally, approximate the right-hand side around $\mu = 1/2$ and hold the density constant, with $F(\Delta') = f(\frac{1}{2f} + \Delta')$ taking the form of a uniform distribution around its midpoint. Defining $\varkappa = (1-\upsilon) f$ gives expression (6) in the text.

Although we have motivated the model by socialization by biological 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 – see Besley and Persson (2020) for a derivation of a similar expression in an organizational setting with socialization by cultural parents.

A.2 Indirect Utilities Let $\hat{y}(t) = [\mu\hat{y}(1, \zeta + t) + (1-\mu)\hat{y}(0, \zeta + t)]$ and $\hat{Y}(T) = [\mu\hat{y}(1, T) + (1-\mu)\hat{y}(0, T)]$. Then write

$$V(T,t) = R(t,T,\gamma) + D(t,T,\gamma) + u(0,t,T,\gamma) - \gamma p\hat{y}(0,\zeta+t) - (1-\gamma) P\hat{Y}(0,T) - \lambda(1-\gamma)\hat{Y}(T)$$

and

$$v(T,t) = R(t,T,\gamma) + D(t,T,\gamma) + u(1,t,T,\gamma) - \gamma p\hat{y}(1,t) - (1-\gamma) P\hat{Y}(1,T) - \lambda(1-\gamma)\hat{Y}(T)$$

where

$$u(\Gamma,t,T,\gamma) = \frac{\gamma\left[\hat{y}(\Gamma,\zeta t)^{1-\sigma}\right] + (1-\gamma)\left[\hat{Y}(\Gamma,T)^{1-\sigma}\right]}{1-\sigma},$$

$$R(t,T,\gamma) = I + \gamma\hat{y}(t)[p - (\chi + \zeta + t)] + (1-\gamma)\hat{Y}(T)[P - (\chi + T)]$$

and

$$D(t,T,\gamma) = t\gamma\hat{y}(t) + T(1-\gamma)\hat{Y}(T).$$

Finally, note that we can write aggregate utility $\mu v(t,T) + (1-\mu)V(t,T)$ as

$$I + \mu u(1,t,T,\gamma) + (1-\mu)u(0,t,T,\gamma) - (\chi+\zeta)\gamma\hat{y}(t) - (\chi+\lambda)(1-\gamma)\hat{Y}(T) \tag{35}$$

A.3 Probability of winning A brown swing voter supports party A if

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

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

Integrating over η, we can now find the share of brown swing voters who vote for party A:

$$\frac{1}{2} + E\left[V(t^A, T^A) - V(t^B, T^B) + \zeta\right]. \tag{36}$$

We assume an interior solution – i.e., (36) lies strictly in the unit interval. A parallel expression holds for green swing voters.

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

$$\zeta + \Psi\left(t^A, T^A, t^B, T^B, \mu\right) \geq 0, \tag{37}$$

where

$$\Psi\left(t^A, T^A, t^B, T^B, \mu\right) = \mu\left[v(t^A, T^A) - v\left(t^B, T^B\right)\right] + (1-\mu)\left[V(t^A, T^A) - V\left(t^B, T^B\right)\right].$$

The first term in (37) is positive if the realized aggregate shock ζ favors party A, while the second is positive if the party's policy platform allows it to court swing voters.

Integrating over ζ (and exploiting the uniform density), gives us the probability that party A wins the election:

$$z^A = \frac{1}{2} + X\Psi\left(t^A, T^A, t^B, T^B, \mu\right), \tag{38}$$

assuming an interior solution.[22] Party B wins with the complementary probability $z^B = 1 - z^A = \frac{1}{2} - X\Psi\left(t^A, T^A, t^B, T^B, \mu\right)$. Each party's probability of winning is thus given by the same function. Given the expression for $\Psi\left(t^A, T^A, t^B, T^B, \mu\right)$, this common objective function is concave. Moreover, it is "as if" each party is maximizing a Utilitarian social-welfare function defined over the short-run parental payoffs. This is a useful benchmark, as the political equilibrium maximizes static welfare, i.e. maximizes (35), as do classic Pigouvian taxes.

[22] This will always be the case if X is small enough – i.e., there is a wide enough support for aggregate shock ζ.

A.4 Political objectives with lobbying

We assume that the coalition of green firms agrees on contributions that maximize the expected profits of their sector which is:

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

and

$$z^A\hat{\Pi}(T^A) + (1 - z^A)\hat{\Pi}(T^B) - \frac{1}{2}[(c^A)^2 + (c^B)^2]$$

where $\hat{\pi}(t) = \hat{y}(t)[p - (\chi + \zeta + t)]$ and $\hat{\Pi}(T) = \gamma\hat{Y}(t)[P - (\chi + T)]$. The total contributions collected by each party are $\gamma\phi c^P + (1-\gamma)\Phi C^P$.These monies (or other resources) 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 (38), the probability of winning, as

$$z^A = \frac{1}{2} + X\{\Psi\left(T^A, t^A, T^B, t^B, \mu\right) + \sqrt{\xi}[\gamma\phi c^A + (1-\gamma)\Phi C^A - (\gamma\phi c^B + (1-\gamma)\Phi C^B)]\}. \tag{39}$$

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

Using (39), we obtain optimal green-firm contributions as

$$c^A = \max\{0, X\sqrt{\xi}[\hat{\pi}(t^A) - \hat{\pi}(t^B)]\} \text{ and } c^B = \max\{0, X\sqrt{\xi}[\hat{\pi}(t^B) - \hat{\pi}(t^A)]\}. \tag{40}$$

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

$$C^A = \max\{0, X\sqrt{\xi}[\hat{\Pi}(T^A) - \hat{\Pi}(T^B)]\} \text{ and } C^B = \max\{0, X\sqrt{\xi}[\hat{\Pi}(T^B) - \hat{\Pi}(T^A)]\}. \tag{41}$$

Next, we substitute the optimal contributions in (40) and (41), integrate these up over all firms, and substitute the result into (39) to get

$$\begin{aligned} z^A &= \frac{1}{2} + X\{\Psi\left(T^A, t^A, T^B, t^B, \mu\right) + \\ &\quad X\xi[\phi\gamma(\hat{\pi}(t^A) - \hat{\pi}(t^B)) + \Phi(1-\gamma)(\hat{\Pi}(T^B) - \hat{\Pi}(T^A))]\}. \end{aligned} \tag{42}$$

Compared to (38), 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.

A.5 Implications of Activism We can now write profits as $\Pi(T, \mu) = \sigma\kappa(T + \mu d(\lambda))[1 - \mu g]$ and $\pi(t, \mu) = \sigma\kappa(\zeta + t - \mu a(\lambda))[1 + \mu g]$. These modifications alter the earlier expression for the green share of firms to

$$\gamma' = \hat{\gamma}(\mu') = \sigma \frac{\kappa(\zeta + t' - \mu' a(\lambda))[1 + \mu' g] - \kappa(T' + \mu' d(\lambda))[1 - \mu' g]}{m}. \tag{43}$$

It is straightforward to see that the share of green firms with endogenous taxes is higher than under laissez-faire, as long as $T' > 0 > t'$. Because κ is decreasing, the green-goods share γ' is positive even with a zero share of green consumers $\mu' = 0$, as long as $\zeta + t' < T'$. Generally, as the green-consumer share goes up, the relative profitability of green production rises goes up because of higher activism.

Substituting $\hat{\gamma}(\mu')$ into (23), we can rewrite the basic result in (12) as follows:

$$\Delta' = \delta(\mu') = \hat{\delta}_0(\mu') + \hat{\delta}_1(\mu')\mu',$$

where

$$\hat{\delta}_0(\mu') = \frac{\sigma g}{1-\sigma}\left[\frac{\sigma[\kappa(\zeta + t' - \mu' a(\lambda))^2 - \kappa(T' + \mu' d(\lambda))^2]}{m} - \kappa(T' + \mu' d(\lambda))\right], \tag{44}$$

and

$$\hat{\delta}_1(\mu') = \frac{\sigma^2 g^2}{1-\sigma}\frac{[\kappa(\zeta + t' - \mu' a(\lambda)) + \kappa(T' + \mu' d(\lambda))]^2}{m} > 0. \tag{45}$$

B Proofs

Several of the proofs below will use special cases of the following result.

Lemma: *Let $\tilde{\lambda}$ be the cost of pollution, $\tilde{\chi}$ be the cost of producing brown goods, $\tilde{\zeta}$ be the additional cost of producing green goods. Then with lobbying, the optimal policies are*

$$T = \frac{(1-\sigma)\tilde{\lambda} - \sigma\tilde{\chi}(1 + \Phi\xi(1-\sigma))}{1 + \Phi\xi(1-\sigma)\sigma} \quad \text{and} \quad t = -\sigma\left(\tilde{\chi} + \tilde{\zeta}\right)\frac{(1 + \xi\phi(1-\sigma))}{(1 + \xi\phi(1-\sigma)\sigma)}.$$

Proof. Observe that (using the envelope condition)

$$\hat{\pi}_t(t) = -\hat{y}(t)$$

and

$$\hat{\Pi}_T(T) = -\hat{Y}(T).$$

Using $\Pi(T,\mu) = \sigma\kappa(T)[1-\mu g]$ and $\pi(t,\mu) = \sigma\kappa(\zeta+t)[1+\mu g] - S[mi]$ and (21), we can write each party's problem as maximizing

$$I + \mu u(1,t,T,\gamma) + (1-\mu)u(0,t,T,\gamma) - \left(\tilde{\chi}+\tilde{\zeta}\right)\gamma\hat{y}(t) - \left(\tilde{\chi}+\tilde{\lambda}\right)(1-\gamma)\hat{Y}T$$
$$+\xi[\phi\gamma(\hat{\pi}(t) + \Phi(1-\gamma)(\hat{\Pi}(T))] - \frac{\gamma^2 m}{2}.$$

The optimum T satisfies

$$\begin{aligned}\frac{\partial\left[\mu\frac{a\hat{Y}(1,T)^{1-\sigma}}{1-\sigma} + (1-\mu)\frac{a\hat{Y}(0,T)^{1-\sigma}}{1-\sigma}\right]}{\partial T} - \left(\tilde{\chi}+\tilde{\lambda}\right)\frac{\partial\hat{Y}(T)}{\partial T} &= \left[\frac{\tilde{\chi}+T}{1-\sigma} - \tilde{\lambda}\right]\frac{\partial\hat{Y}(T)}{\partial T} \\ &= \xi\Phi Y(t).\end{aligned}$$

Using $\hat{Y}(t) = [1-\mu g]\left(\frac{\tilde{\chi}+T}{1-\sigma}\right)^{-\frac{1}{\sigma}}$, we have

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

This yields

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

Solving this for T gives the result. Analogously, for t, the optimum condition is

$$\begin{aligned}\frac{\partial\left[\mu\frac{a\hat{y}\left(1,\tilde{\zeta}+t\right)^{1-\sigma}}{1-\sigma} + (1-\mu)\frac{a\hat{y}\left(0,\tilde{\zeta}+t\right)^{1-\sigma}}{1-\sigma}\right]}{\partial t} - \left(\tilde{\chi}+\tilde{\zeta}\right)\frac{\partial\hat{y}(t)}{\partial t} &= \left[\frac{\tilde{\chi}+\tilde{\zeta}+t}{1-\sigma} - \tilde{\chi} - \tilde{\zeta}\right]\frac{\partial\hat{y}(t)}{\partial t} \\ &= \xi\phi\hat{y}(t).\end{aligned}$$

Now, observe that $\hat{y}(t) = [1+\mu g]\left(\frac{\tilde{\chi}+\tilde{\zeta}+t}{1-\sigma}\right)^{-\frac{1}{\sigma}}$ so

$$\frac{\hat{y}(t)}{\partial\hat{y}(t)/\partial t} = -\sigma\left(\tilde{\chi}+\tilde{\zeta}+t\right).$$

Then, the optimal tax/subsidy solves

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

■

Proposition 1 Proof. This is a special case of Proposition 4, when $T=t=0$, and is hence omitted. ■

Proposition 2 Proof. This follows from the Lemma, when $\phi=\Phi=0$, $\tilde{\chi}=\chi$, $\tilde{\lambda}=\lambda$ and $\tilde{\zeta}=\zeta$. ■

Proposition 3 Proof. This follows from the Lemma, when $\tilde{\chi}=\chi$, $\tilde{\lambda}=\lambda$ and $\tilde{\zeta}=\zeta$. ■

Proposition 2′ Proof. This follows from the Lemma, when $\phi=\Phi=0$, $\tilde{\chi}=\chi+\mu\theta$, $\tilde{\lambda}=\lambda$ and $\tilde{\zeta}=\zeta$. ■
Proposition 2″
Proof. This follows from the Lemma, when $\phi=\Phi=0$, $\tilde{\chi}=\chi+\mu d(\lambda)$, $\tilde{\lambda}=\lambda$ and $\tilde{\zeta}=\zeta-\mu a(\lambda)$. ■

Proposition 4 Proof. First observe that

$$\hat{\delta}_0+\hat{\delta}_1\mu$$

is increasing in μ (including the case with political activism). To see this, note that

$$\begin{aligned}\Delta' &= \hat{\delta}_0+\hat{\delta}_1\mu' \\ &= \frac{\sigma g}{1-\sigma}\left[\gamma'(\mu')\kappa(\zeta-\mu' a(\lambda)+t')-(1-\gamma'(\mu'))\kappa(\mu d(\lambda)+T')\right],\end{aligned}$$

where

$$\gamma'(\mu')=\frac{\sigma(1+\mu' g)\kappa(\zeta-\mu' a(\lambda)+t')-\sigma(1-\mu' g)\kappa(\mu' d(\lambda)+T')}{m}.$$

Let $\kappa_1(\mu') = \kappa(\zeta - \mu' a(\lambda) + t')$, and $\kappa_2(\mu') = \kappa(\mu d(\lambda) + T')$. Observe that

$$\begin{aligned}
\frac{\partial \kappa_1}{\partial \mu'} &= \frac{\partial [\zeta + \chi - \mu' a(\lambda)]^{\frac{\sigma-1}{\sigma}}}{\partial \mu'} = \frac{1-\sigma}{\sigma}[\zeta + \chi - \mu' a(\lambda)]^{-\frac{1}{\sigma}} a(\lambda) > 0; \\
\frac{\partial \kappa_2}{\partial \mu'} &= \frac{\partial [\lambda + \chi + \mu' d(\lambda)]^{\frac{\sigma-1}{\sigma}}}{\partial \mu'} = \frac{\sigma-1}{\sigma}[\lambda + \chi + \mu' d(\lambda)]^{-\frac{1}{\sigma}} d(\lambda) < 0.
\end{aligned}$$

Now differentiating $\hat{\delta}_0(\mu') + \hat{\delta}_1(\mu')\mu'$ with respect to μ' yields:

$$\begin{aligned}
\frac{\partial \Delta'}{\partial \mu'} &= \frac{\sigma g}{1-\sigma}\left[\frac{\partial \gamma'}{\partial \mu'}(\kappa_1 + \kappa_2) + \gamma' \left(\frac{\partial \kappa_1}{\partial \mu'} + \frac{\partial \kappa_2}{\partial \mu'}\right) - \frac{\partial \kappa_2}{\partial \mu'}\right] \\
&= \frac{\sigma g}{1-\sigma}\left[\frac{\partial \gamma'}{\partial \mu'}(\kappa_1 + \kappa_2) + \gamma' \frac{\partial \kappa_1}{\partial \mu'} + (\gamma' - 1)\frac{\partial \kappa_2}{\partial \mu'}\right]
\end{aligned}$$

and

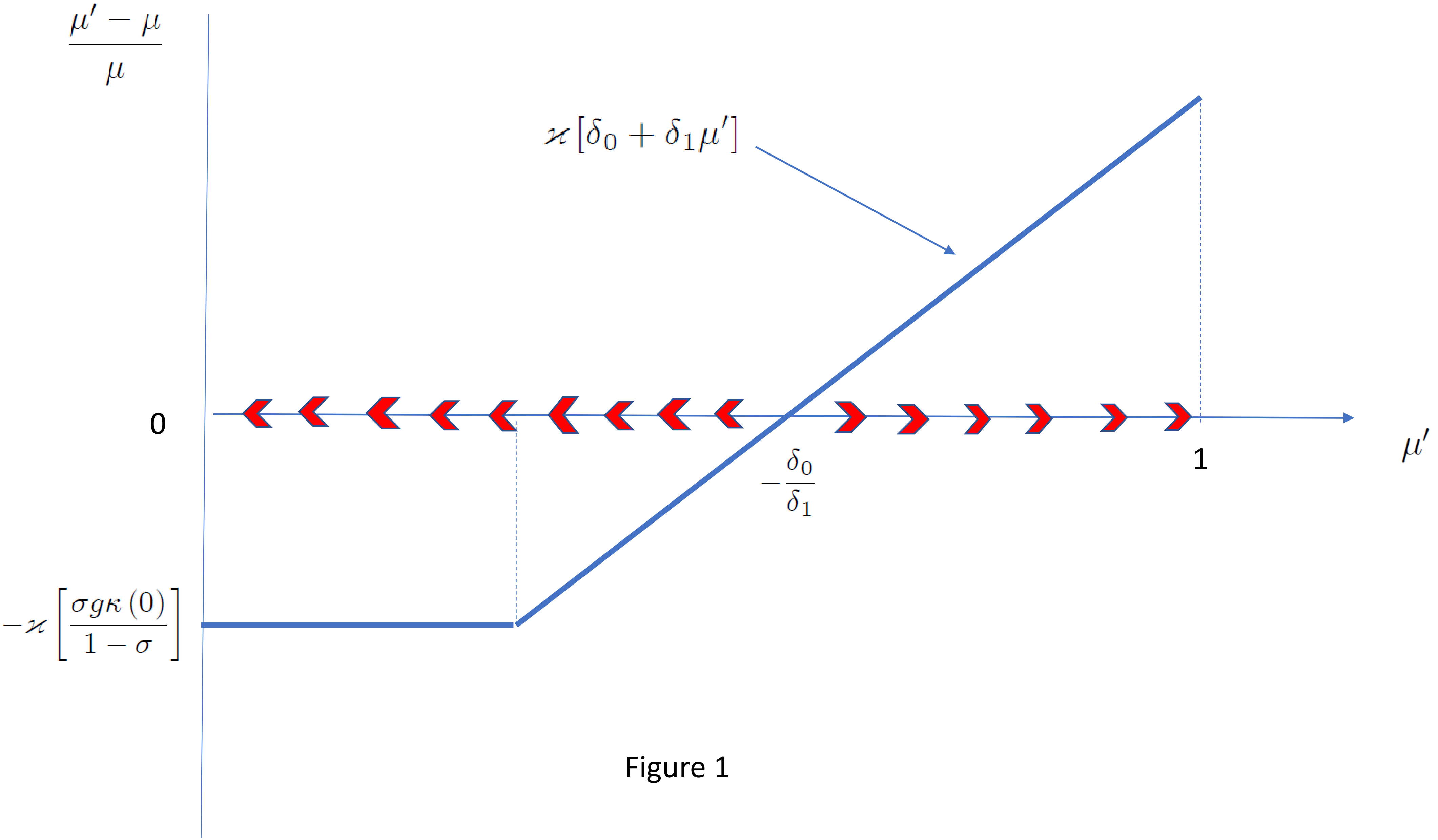
$$\begin{aligned}
\frac{\partial \gamma'}{\partial \mu'} &= \frac{\sigma}{m}\left[g(\kappa_1 + \kappa_2) + g\mu' \left(\frac{\partial \kappa_1}{\partial \mu'} + \frac{\partial \kappa_2}{\partial \mu'}\right) + \left(\frac{\partial \kappa_1}{\partial \mu'} - \frac{\partial \kappa_2}{\partial \mu'}\right)\right] \\
&= \frac{\sigma}{m}\left[g(\kappa_1 + \kappa_2) + (1 + g\mu')\frac{\partial \kappa_1}{\partial \mu'} + (g\mu' - 1)\frac{\partial \kappa_2}{\partial \mu'}\right].
\end{aligned}$$

Because $g, \mu, \gamma < 1$, both $\frac{\partial \gamma'}{\partial \mu'}$ and $\frac{\partial \Delta'}{\partial \mu'}$ are positive.

We also note that

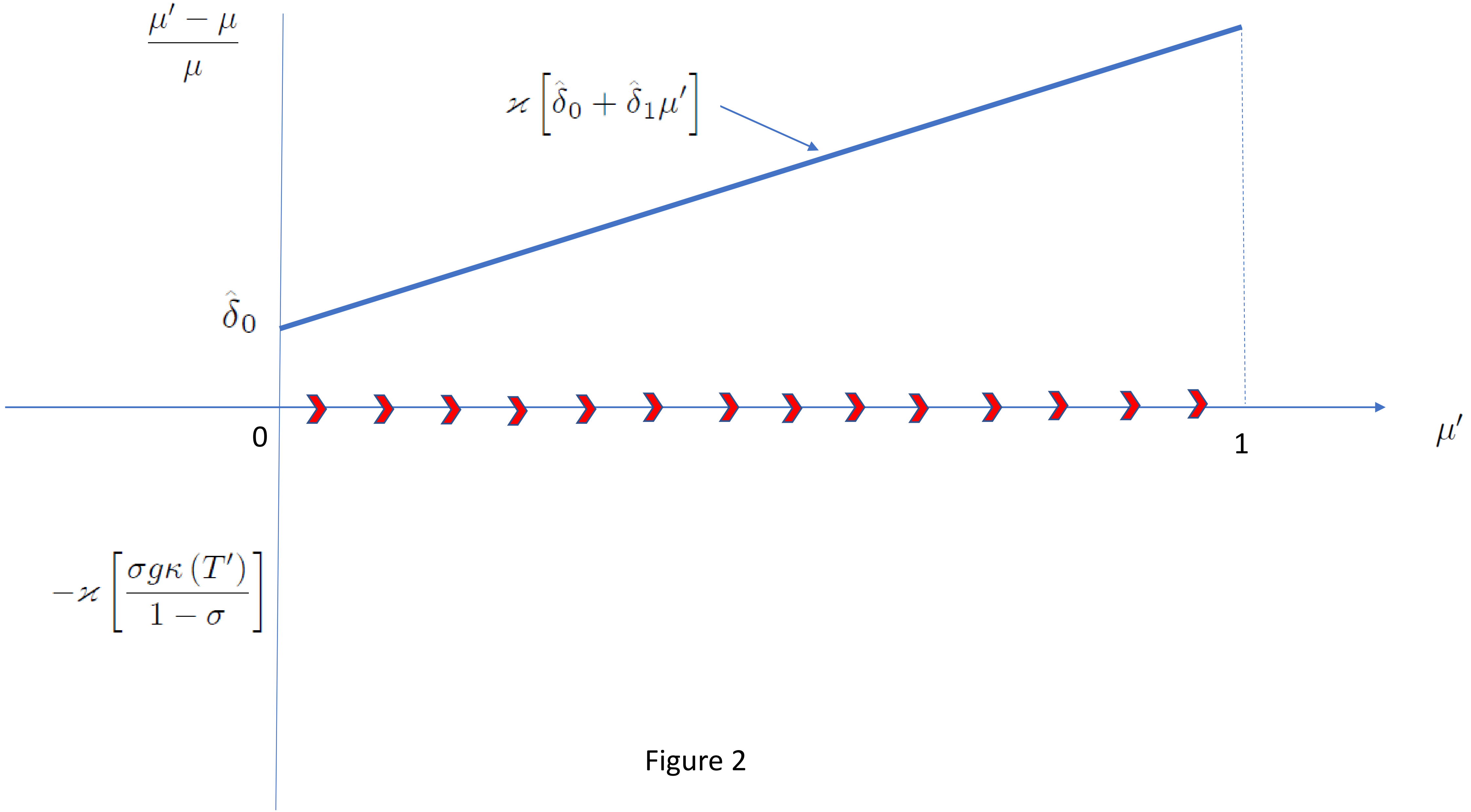
$$-\frac{\sigma g \kappa(T')}{1-\sigma} < \hat{\delta}_0.$$

Now, if $\hat{\delta}_0 > 0$, then $\Delta' > 0$ and hence $\mu' - \mu > 0$ so the only steady state has $\mu = 1$. Consider instead the case where $\hat{\delta}_0 < 0$. If $\widehat{\mu} \leq -\widehat{\delta}_0/\widehat{\delta}_1$ holds, then $\Delta' < 0$. Moreover $\mu' - \mu < 0$, and the only steady-state has $\mu = 0$. If $\widehat{\mu} > -\widehat{\delta}_0/\widehat{\delta}_1$ then $\widehat{\delta}_0 + \widehat{\delta}_1\mu' > -\frac{\sigma g \kappa(T')}{1-\sigma}$, and $\Delta' > 0$. Hence $\mu' - \mu > 0$, so the only steady state is where $\mu = 1$. ■



$\frac{\mu' - \mu}{\mu}$
$\varkappa\left[\delta_0 + \delta_1 \mu'\right]$
0
$-\frac{\delta_0}{\delta_1}$
1
μ'
$-\varkappa\left[\frac{\sigma g \kappa(0)}{1-\sigma}\right]$

Figure 1



$\frac{\mu' - \mu}{\mu}$
$\varkappa\left[\hat{\delta}_0 + \hat{\delta}_1 \mu'\right]$
$\hat{\delta}_0$
0
1
μ'
$-\varkappa\left[\frac{\sigma g \kappa (T')}{1-\sigma}\right]$

Figure 2