Responsible Investment and Responsible Consumption*

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Abstract

To reduce a negative externality, socially responsible households can *invest* responsibly (SRI), *consume* responsibly (SRC), or do both. Which is better? In a closed microeconomic model with intertwined product and capital markets, we show that the greatest responsible impact is achieved by a proportional combination of SRI and SRC. This prevents price changes and corresponding market responses that would partly offset the responsible choice. A mere focus on SRC is inefficient; SRI should be part of any responsible action. The responsible investment's relative financial performance is determined by the households' ability to commit to the efficient exit and boycott strategy.

Keywords: Socially responsible investment (SRI), socially responsible consumption (SRC), sustainable investment, green finance, ESG, SPI.

JEL-Classification: G30, G23, D62, D64, D16, M14.

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1 Introduction

Today, the need for a more sustainable economy is on the top of the agenda of policy makers, investors, and consumers. However, responsible households may wonder if their individual investment or their consumption choices are the best way to impact the negative externality. The reallocation of investments from dirty to clean companies is supposed to affect the funding costs and thus the supply from firms.[1] However, forgoing high-yielding investment and diversification opportunities could lead to a loss of household income. Simply discarding dirty investments might not even be effective, as other investors may compensate for the reduction. Symmetric arguments apply to responsible consumption. Giving up dirty goods narrows down consumption choices, and scorned goods may be bought by less scrupulous households who substitute for the responsible choice. As households are usually both investors and consumers, the question arises whether retail investments are actually the right place to exert pressure? Or would the impact of households on the product market be greater?

By adding a product market to Heinkel et al. (2001), our model provides the first theoretical analysis of this question: If households are willing to sacrifice some of their utility to cut an externality, should they focus more on avoiding dirty investments (SRI), or should they focus on boycotting dirty consumption (SRC)? Responsible households can choose to contribute to a negative externality abatement by affecting the supply side via their investment in the primary capital market and the demand side via their consumption choices. The responsible choice has direct and indirect effects through market prices and the corresponding impact on the other households' consumption and investment decisions. We explicitly acknowledge that both markets are intertwined: the cost of capital influences product prices as much as product market profits affect investment yields. When choosing how to exert their impact,

[1] In this paper we will use the terms "clean" ("dirty") to refer to a production that causes low (high) negative externalities. The wording suggests an environmental externality, but the model also applies to social or other externalities.

responsible households anticipate the responses of other market participants. In our model, firms produce a good that entails a negative externality. Households first invest into firms in the primary capital market and then spend the investment return on consumption. A fraction of households is "responsible" and takes the externality of their decision into account, at least partially.[2] Firms use the invested money to produce goods, then sell the goods on a competitive market, earn revenue, and suffer from a profit shock.

We show that SRI and SRC are both effective and have a direct, symmetric, and proportional impact in reducing a negative externality. Moreover, both choices are intertwined and influence the efficiency of each other: If some households stop consuming the product, financing the production becomes less attractive, leading to a decreased production, and thus to a decreased externality. However, as prices drop, less scrupulous consumers increase their consumption, partially compensating for the initial reduction. Most strikingly, we show that households can fully avoid the offset of their responsible renunciation by exploiting the opposing price effects of each action. Reducing investment directly increases the yield, but indirectly also increases the product prices because it makes the product scarcer. Similarly, boycotting the product directly decreases the product prices due to less demand, but this indirectly also decreases yields as the firm investment becomes less valuable to other investors because of lower product market profits. Both actions' direct price effects are offset by the other action's indirect effect. More generally, responsible households have the highest impact if their actions do not change asset returns and product prices. In our symmetric model, the responsible choice has the greatest impact if investment is reduced in proportion to the consumption boycott.[3]

We begin our analysis with a normative question: How should households reduce their

[2] If responsible households had political clout, they could convince the policy maker to introduce a Pigovian tax on the good with the negative externality. In this paper, we assume that this political path is not an option. One reason might be that responsible households do not have a majority or that the externality occurs globally, whereas the political system is implemented at regional levels.

[3] In Section 3.1 we show that introducing asymmetries between households can push the optimal mix towards favoring consumption or investment reduction, depending on which action has a stronger effect on the asymmetric force. However, on average, the proportionality result remains.

consumption and investment if they want to maximize their impact on the externality? Given the optimal behavior and responses of standard households, we derive the *efficient* combination of responsible investment and consumption for any target impact level. We show that this result is independent of why households act responsibly, how many they are, and how they coordinate. We then discuss the households' optimal *target level* for reducing the externality. It depends on economic uncertainty, risk aversion, relative product preferences, and the commitment mechanism available to responsible households.

Responsible households face a series of commitment problems. *First* of all, it is individually rational to choose the same level of investment and consumption as standard households. To make responsible households different from standard households, we therefore must assume that responsible households have either the ability to coordinate their choices as a group, or that their utility function includes an altruistic element. In our analysis, we focus on the coordination assumption and investigate the effect of different commitment mechanisms[4] Allowing responsible households to be altruistic would yield the same normative insights, but would affect the positive analysis as the target impact chosen would depend on the specific utility function.*Second*, at the time of consumption, the goods are already produced. It is too late to influence the level of production. Therefore, responsible households need to commit ex-ante to some consumption level that is anticipated at the production stage. A responsible entity could ensure this commitment with a tax on dirty consumption. Households alone would need other commitment devices such as social norms and peer pressure.[5] Later on, in Section 5, we discuss different commitment devices such as taxes, social norms, and peer pressure and their impact on the optimal responsible behavior. We also discuss the implications of imperfect commitment for our results. *Third*, although there are no secondary markets in our model, in reality, shares are typically bought on stock exchanges. This cre-

[4]The ability to coordinate is a common assumption in the literature on responsible investors (see e. g. Oehmke and Opp, 2020; Broccardo et al., 2020).

[5]White et al. (2019) summarize empirical evidence that social norms are one of the most effective mechanisms to elicit pro-environmental behaviors in consumption.

ates a time consistency problem also for investments. At the time of the share purchase, it is too late to influence the firms' investment and output levels. Therefore, households can only influence firm behavior if they can commit to an investment level ex-ante.[6] If such a credible commitment is feasible, the anticipation of prices on the secondary market influences the prices and volumes at the IPO. In our model,we focus on primary market investments. However, a scenario where commitment in secondary financial markets is difficult or impossible is embedded in our model, see Section 5.3.

Our study makes three major contributions to the literature on green finance. *First*, we develop a tractable basis model to evaluate the impact of green investment in a general equilibrium with feedback effects through other markets. This provides a formal framework that allows us to address the substantial skepticism towards the effectiveness of responsible household impact.(Brest et al., 2018; Krahnen et al., 2021; Berk and van Binsbergen, 2021)[7] The main argument against green investment efficiency and responsible boycott impact is the market response of less scrupulous investors and consumers, which compensates (at least partially) responsible behavior (Heinkel et al., 2001; Broccardo et al., 2020). However, this argument overlooks that responsible households are usually active in both markets, directly or through intermediaries, and therefore have at least two margins to affect the externality. Their relative effectiveness is determined by individual risk aversion and consumption preferences of standard households, which each alter the market response to price changes. Each margin has opposite effects on the equilibrium prices, so that they stimulate opposing market responses. Abstaining from dirty investments reduces production, which increases product prices and investment yields. Boycotts, in contrast, reduce product prices and expected investment yields.

Second, we show that optimal responsible choicefully eliminates the partial offset of their

[6] Hong and Kacperczyk (2009); Zerbib (2022) document the effects of social norms on capital markets and stock prices.

[7] An example of the public discourse in this vain is the interview with Bill Gates published in the Financial Times, in which he states that "Divestment, to date, probably has reduced about zero tonnes of emissions." https://www.ft.com/content/21009e1c-d8c9-11e9-8f9b-77216ebe1f17.

sacrifice by complementing responsible investment with proportional boycott of consumption. Because households are investors and consumers at the same time, their actions become more efficient. Intuitively, withholding the amount of capital from a dirty firm that becomes redundant due to a commitment to reduce dirty consumption forces the firm to scale back production while leaving the equilibrium prices and returns unchanged. In contrast, any disproportionate effort in one market would affect the equilibrium returns and prices, thereby changing the investment and consumption decisions of standard households whose adjustments would substitute, at least partially, for the responsible household's choices rendering them less efficient. Interestingly, this proportionality result does not depend on the level of risk aversion or the substitutability of the product.[8] If risk aversion is low, it is inexpensive to reduce investment in the dirty industry, but other investors also have a low risk aversion and thus adjust their investment accordingly. Therefore, the cost is low, but the effect is also low. Moreover, we investigate which assumptions are crucial for the proportionality outcome. We characterize the optimal disproportionate efforts when responsible households have divergent product preferences from the general market and for a general class of non-linear production functions. In those cases, a high impact goal can even imply corner solutions to be optimal. On the contrary, the proportionality result remains to hold if standard and responsible households have heterogeneous preferences on risk and product substitutability.

Third, we investigate the conditions under which efficient responsible choices are implementable by a responsible group of households. We show that the implementation of proportional reductions is only feasible if taxes are moderately efficient. If taxes are inefficient or unfeasible, such that commitment must be driven by social norms at costs, corner solutions arise. Households optimally focus on consumption or investment first. Moreover, we show that, if households cannot costlessly commit to responsible behavior in both markets,

[8]SRI would not have an impact on corporate behavior in the absence of risk or risk aversion because even though responsible investors eschew dirty stocks, their investments would be perfectly substituted by less ethical investors. Similarly, responsible consumption choices would be entirely offset if goods were perfect substitutes. We discuss the importance of households' need for diversification in Section 3.1.

the financial performance of dirty investments relative to a comparable clean investment is affected. If households can commit only to SRC but not to SRI, the responsible choice increases the yield of dirty shares compared to a similar clean investment and vice versa.

Literature. Socially responsible households in our model want to behave pro-socially as proposed in Bénabou and Tirole (2010): They are willing to sacrifice utility to reduce a negative externality. Although the assumption of altruistic households would yield the same results for our first two propositions, we focus on coordinated choices of rational agents in the discussion of social welfare. The willingness of responsible investors to forgo financial performance to invest according to their social preferences is well documented (Renneboog et al., 2011; Riedl and Smeets, 2017; Barber et al., 2021). The research on responsible consumption, however, is mainly focused on consumer behavior and the question of what drives consumer's commitment to responsible choices (Nguyen et al., 2019; White et al., 2019; Bernard et al., 2022). Bolton and Kacperczyk (2021) find evidence that investors demand to be compensated for their exposure to carbon risks. Luo and Balvers (2017) find evidence that investors also demand a premium for consumer boycott risks. In contrast, our article contributes to the literature by analyzing the interaction between responsible investment, production, and consumption.

The choices of responsible households in our model reflect the moral concept of direct consequentialism, as discussed in Moisson (2021) because households are concerned with the direct impact of their investment and consumption decisions. Chowdhry et al. (2018) analyze conditions under which the joint financing of purely profit-oriented and socially responsible investors improves social outcomes. Similarly, Oehmke and Opp (2020) analyze the impact of socially responsible investment on the production technology choices of financially constrained firms. We complement this literature by showing that SRI can not only influence the choice of technology, but also be efficient in directly reducing the production quantities. In particular, we show that if households simultaneously boycott a dirty firm, a reduction in the investment is not replaced by other market participants and, therefore, directly translates into a reduced production of the externality.

Our model is closest to Heinkel et al. (2001) who show that the risk-sharing friction alters the equilibrium funding costs of firms such that a decrease in investment from responsible households results in dirty firms switching to invest to a more sustainable production. We extend their capital market model with a product market. This allows us to emphasize an additional friction to the impact of green investment. A lower production of the dirty good forces the product market prices to increase, which also increases the marginal yield on investment, so that more standard investors are willing to invest in the first place, which partially compensates for the responsible investment reduction. This effect has been empirically documented by Zerbib (2022) who show that the focus of investors on SRI stocks improves the relative financial performance of sin stocks. The key contribution of our model is to show that responsible households can fully prevent this attenuation of their responsible investment reduction by also committing to consume less from dirty firms.

Broccardo et al. (2020) analyze the relative effectiveness of investment exit or consumer boycott and compare it with the efficiency of strategies that directly influence management decisions (voice), which they find to be the most effective strategy if responsible investors own the majority of shares. On the contrary, we argue that investors are also typically consumers, and thus investment exit and boycott are not substitutes, but complement each other in a responsible strategy. Because households can do both simultaneously: consume less *and* invest less, exit and boycott become efficient. We show that responsible households can directly reduce the externality without allowing other market participants to offset their choices by not providing the capital needed to produce the amount of product, which they also boycott. This implies that retail investors can have a responsible impact even if they do not have a voice or are in the minority.

These synergies between SRI and SRC have been largely neglected in the literature. A remarkable exception is Albuquerque et al. (2019), who analyze how SRI can increase firm profitability due to an increase in the loyalty of their customer base. In our model, responsible households are also more sensitive to price changes in dirty goods, but we focus on the question of how responsible households can maximize their responsible impact on abatement with their consumption and investment choices.

The remainder of the paper is organized as follows. Section 2 introduces the model, including socially responsible households, presents our main results and analyzes the robustness towards alternative assumptions (heterogeneity in preferences, alternative production functions). Section 5 investigates how responsible households can commit to a sacrifice. Section 6 concludes. All proofs are in the Appendix A.

2 The Model Setup.

Consider a two period economy with a continuum of households, a production sector that creates a negative externality (a continuum of dirty firms) and the (clean) rest of the economy. The *gross* risk-free rate in this economy is r_f.[9] Dirty firms receive an aggregate investment I, which they use to produce the dirty good at a constant marginal cost $c > 0$.[10] The aggregate quantity of the good produced is $Q = I/c$. Goods are sold to households at the market clearing price P. The production and consumption of the good generate an externality x per unit of investment that can be positive or negative.[11] We focus on the negative externality case. After production, each firm liquidates its assets and recovers $(\lambda + \varepsilon)\, I$ where λ is the

[9] We assume that households can invest and borrow at this risk free rate if needed.

[10] The simplification of a linear production function keeps the model simple and allows us to get tractable results. We discuss in Section 3.2 that any production function $Q(I)$ can be linearly approximated locally. Based on this approximation, we add a qualification to our results regarding the specific characteristics of a general production function.

[11] Due to the linear production technology, input and output are proportional, hence it does not matter whether the externality occurs in the production process or with consumption. We can simply denote $x = x_{\mathrm{C}}/c + x_{\mathrm{P}}$ as the aggregate externality, with $x\, I = x_{\mathrm{C}}\, Q + x_{\mathrm{P}}\, I = x_{\mathrm{C}}\, I/c + x_{\mathrm{P}}\, I$.

$t = 0$

- Households born with wealth w_0.
- Firms have no capital.
- *Primary capital market:* Each household invests i into firms.
- *Production:* Firms receive aggregate $I = \sum i$ and produce $Q = I/c$ of the dirty good.

$t = 1$

- *Product market:* Firms sell dirty good to households at price P.
- Firms liquidate assets for $(\lambda + \varepsilon) I$.
- Profits are distributed to investors.
- Households consume dirty good and use remaining wealth for other consumption.

Figure 1: Sequence of Events

average liquidation value per unit of investment, and $\varepsilon \sim N(0, \sigma)$ is an exogenous shock.[12] This shock introduces risk into the per dollar investment return $r = P/c + \lambda + \varepsilon$ as firms distribute all final profits to their investors. Figure 1 summarizes the timeline of the model.

Households are risk-averse with exponential utility $u(c) = -e^{-\rho C}$ where ρ measures their constant absolute risk aversion and C the final amount of consumption. Households have concave preferences for the consumption of the dirty good $a - \frac{bq^2}{2}$ where the quantity of the dirty good consumed is q, the preference for the product is a, and b measures the substitutability with other products.[13] In addition to consuming the dirty good, households derive utility from money that they can use to consume another good (the clean numéraire) outside the focus of this model. As such, the standard responsible investment problem that was introduced by Heinkel et al. (2001) is embedded in our model if we set $b = 0$.

According to the literature (Heinkel et al., 2001; Broccardo et al., 2020), we assume the utility of CARA to keep our model simple and tractable. This allows us to focus on the interaction between the two markets altering the impact on the externality. This implies that households' investment and consumption decisions are separable. We can therefore

[12] The liquidation value can also be interpreted as the firm's stock price in a multi-period model, so that the noise simply represents the price risk. Alternatively, one could consider a shock that arises from uncertainty in the production process.

[13] We discuss the impact of heterogeneities in household preferences on risk and consumption in Section 3.1.

solve the household decision simultaneously. Moreover, the level of consumer wealth does not affect their optimal consumption or investment choice.[14]

Households are endowed with w_0. Denote a household's investment choice as i_h, the investment in the risk-free asset as $w_0 - i_h$, and the household's consumption choice as q_h, where the subscript $h \in \{S, R\}$ characterizes the type of household.[15] There are two types of households. A fraction $(1-\gamma)$ are *standard* households $h = S$ that do not care about the externality caused by their individual decisions. They invest i_S and consume q_S to maximize their expected utility. A fraction γ is called *responsible* households, i.e., $h = R$. Responsible households want to reduce the negative externality . In exchange for such an impact, responsible households are potentially willing to sacrifice some of their utility. We assume for the moment that households can ex ante commit to some investment and consumption level despite facing several commitment problems. In fact, because responsible households in our model are assumed to have the same preferences as standard households and suffer from the externality in the same way, the access to a commitment technology is the only conceptual difference between standard and responsible households. After determining the optimal responsible choice that maximizes the impact, we analyze different commitment mechanisms that would implement the optimal responsible choices, and we discuss how imperfect commitment in each market would alter the results.

We begin by deriving the optimal choice of standard households given a certain level of responsible investment and consumption. This allows us to define the markets' equilibrium responses and the impact of any responsible investment and consumption choice on the equilibrium output, prices, and externality generated. After characterizing how responsible households' choices affect the equilibrium outcomes, we will derive the optimal choice of

[14]If risk aversion decreased with the level of the original endowment, as well as the realized profits from investment, the optimal decision of households to invest would be altered, which would add further interesting effects to our results that we leave aside in this setup.

[15]As households of the same type are homogenous, they make identical choices and only symmetric equilibria exits. We can, thus, omit an index for each single household.

responsible households with (imperfect) commitment and analyze the feasibility of implementation. The expected utility of standard households is

$$U = -exp\left\{-\rho\left(\underbrace{(w_0 - i_S)r_f + i_S\left(\frac{P}{c} + \lambda + \varepsilon\right)}_{\text{Investment Payoff}} + \underbrace{aq_S - Pq_S - b\frac{q_S^2}{2}}_{\text{Consumption Return}} - \underbrace{x\,I}_{\text{Externality}}\right)\right\}. \quad (1)$$

Given that the risk of investment return ε is normally distributed, maximizing (1) is equivalent to maximizing

$$(w_0 - i_S)r_f + i_S\left(\frac{P}{c} + \lambda + \varepsilon\right) + aq_S - Pq_S - b\frac{q_S^2}{2} - x\,I. \quad (2)$$

Since they are infinitely small, standard households take the price P and the aggregate externality xI as given. The objective function (2) is concave in both q_S and i_S such that the first-order conditions define the optimal equilibrium choices given the endogenous market clearing price P,

$$i_S^* = \frac{P/c + \lambda - r_f}{\rho\,\sigma^2} \quad (3)$$

$$q_S^* = \frac{a - P}{b}. \quad (4)$$

Ceteris paribus, an increase in the equilibrium price P increases the investment of standard household investment and decreases their optimal consumption. These opposite reactions of standard households form the core mechanism in our model. The standard household's optimal choices along with the responsible household's choices i_R and q_R define the aggregate investment

$$I = \gamma\, i_R + (1-\gamma)\left(\frac{\frac{P}{c} + \lambda - r_f}{\rho\,\sigma^2}\right). \quad (5)$$

resulting in an aggregate production of $Q = \frac{I}{c}$. As well as the aggregate demand

$$Q = \gamma\, q_R + (1-\gamma)\left(\frac{a-P}{b}.\right) \tag{6}$$

In equilibrium, markets must clear. The aggregate production must equal the aggregate demand for the dirty good. This pins down the market clearing price $P^*(i_R, q_R)$ as a function of the responsible choice i_R and q_R

$$P^* = \frac{c^2\,\rho\,\sigma^2\,a\; + b\,c\,(r_f - \lambda)}{b + \rho\,c^2\,\sigma^2} + \frac{\gamma}{1-\gamma}\,\frac{b\,c^2\,\rho\,\sigma^2}{(b + c^2\,\rho\,\sigma^2)}\,\big(q_R - {}^{i_R}\!/_{c}\big). \tag{7}$$

The market clearing price is increasing in the amount of responsible consumption q_R and decreasing in the amount of responsible investment i_R. If responsible households boycott the dirty good, the equilibrium price decreases, stimulating higher demand for the good from standard households. The responsible action is offset by the direct market reaction of standard households. However, if responsible households abstain from dirty investments, a lower production increases the price, throttling standard demand for the dirty good. The expected equilibrium return per unit of investment becomes

$$E[r]^* = \frac{c\,\rho\,\sigma^2\,(a + c\,\lambda) + b\,r_f}{b + c^2\,\rho\,\sigma^2} + \frac{\gamma}{1-\gamma}\,\frac{b\,c\,\rho\,\sigma^2}{b + c^2\,\rho\,\sigma^2}\,\big(q_R - {}^{i_R}\!/_{c}\big). \tag{8}$$

If responsible households reduce their investment in the dirty industry, expected returns increase, stimulating investment from standard households, which partially replaces the responsible action. In contrast, a responsible boycott reduces demand for the good, which decreases the expected returns on investment and makes investment less attractive to standard households.

3 The Optimal Combination of Responsible Choices.

We now want to analyze how responsible households should use their two actions to maximize their impact. Let us define for this purpase a benchmark of optimal investment and consumption levels absent any responsible households ($\gamma = 0$) as i_0 and q_0, which we will use as a reference point for responsible choices. To reduce the externality, responsible households can affect the supply side through their investment decision $i_R = i_0 - \Delta i$, where Δi denotes the *exit* of the dirty investment. They can also affect the demand side through their choice of consumption $q_R = q_0 - \Delta q$, where Δq denotes responsible *boycott*. Defining I_0 as the equilibrium quantities invested in the absence of responsible households, we obtain

$$I^* = I_0 - \Delta I = I_0 - \gamma\, c \left(\varphi\, \Delta q + (1-\varphi)\, {}^{\Delta i}/_{c}\right) \tag{9}$$
$$\text{with } \varphi = \frac{b}{b + c^2\, \rho\, \sigma^2}.$$

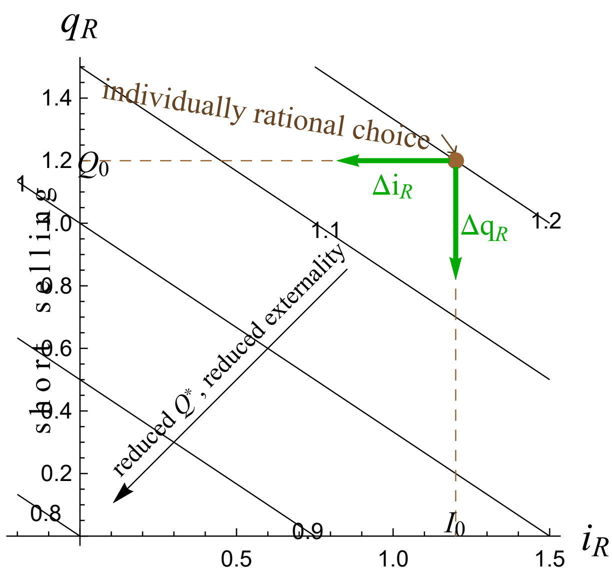
The aggregate negative externality $x\, I^*(\Delta i, \Delta q)$ that arises in equilibrium is a function of the responsible choices Δi and Δq.

Lemma 1 (Effectiveness) *The marginal rate of transformation between a reduction in investment (SRI) and a reduction in consumption (SRC) is*

$$MRT_{\Delta i, \Delta q} = -\frac{(1-\varphi)/c}{\varphi} = -c\, \frac{\rho\, \sigma^2}{b}.$$

All proofs are in the Appendix A. The marginal rate of transformation reflects the amount of dirty consumption that responsible households can additionally consume if they give up a unit of dirty investment and hold their impact on the externality constant. It measures the relative effectiveness between SRI and SRC. The effectiveness $(1-\varphi)/c$ of a reduction in investment i_R increases in asset risk σ, and risk aversion ρ. The effectiveness φ of a reduction in consumption q_R increases in the product specificity b. These parameters specify the steepness of the market response to changes in the equilibrium prices, which determines how much a responsible action is offset by marginal consumers and investors reactions.

Figure 2: Impact of Reducing q_R or i_R



Parameters are $c = 1, \rho = 1/3, a = 2, b = 1/2, x = 1, \gamma = 1/3$, $\lambda = 0$, $\sigma = 1$ and $r_f = 1$.

Figure 2 illustrates the Lemma (1).In the numerical example, $Q_0 = 1.2$, and because $c = 1$, also $I_0 = 1.2$. If there were only standard households ($\gamma = 0$), the externality would be $1.2\,x$. The parallel lines are iso-impact lines; their slope equals the MRT. If responsible households reduce investment or consumption, also the aggregate externality $x\,I$ goes down.

Only at the extreme, in the absence of any risk or risk aversion, investment reduction Δi has no effect. Standard households compensate completely for the reduced investment. However, a reduction in consumption Δq still results in a reduction in aggregate consumption. Boycott Δq decreases the expected profits of the firm, so the equilibrium investment is reduced. Standard households do not compensate for this by consuming more. An analogous effect holds if $b = 0$. In this case, a reduction in consumption Δq has no direct effect on the externality but a reduction in investment in the primary capital market reduces the overall production of the good, increasing prices, and therefore indirectly reducing consumption.

We now analyze which combination of consumption reduction Δq and investment reduction Δi optimizes the trade-off of responsible households between expected utility and impact.

Proposition 1 (Efficiency) *Responsible households have the highest impact on reducing an externality if they reduce investment in proportion their consumption reduction. The efficient responsible behavior satisfies*

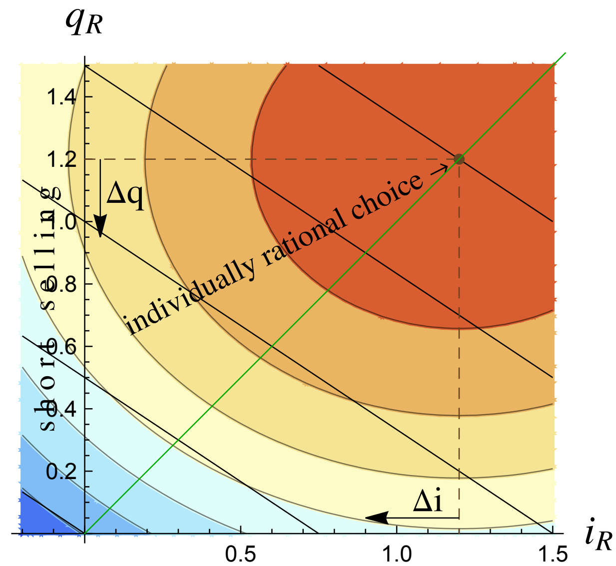
$$\frac{q_R^*}{i_R^*} = \frac{\Delta q^*}{\Delta i^*} = \frac{1}{c}. \tag{10}$$

Proposition 1 follows directly from Lemma 1. Since responsible households can affect the externality with two margins, it is optimal to reduce investment and consumption by the same factor, so that the equilibrium price and the expected return of the investment remain unchanged. Any disproportionate reduction results in market responses of standard households and, therefore, is less effective. This is true for any level risk and risk aversion. If the utility loss of a reduction in investment Δi is low, for example, because risk aversion or risk itself is low, it is also very easy for standard households to substitute for the reduced investment. The same is true for a reduction in q_R. Therefore, the greatest impact results from a proportional reduction in both investment and consumption.

The rationale for maximizing the impact by minimizing the market response is very robust. However, the fixed proportion results from the simple structure in our model, in particular from the CARA utility, the constant returns to scale production, and the homogeneous preferences between the types of households. In 3.1 and 3.2 we relax these assumptions and discuss under which conditions one margin becomes more important than the other. Moreover, in 5 we analyze frictions to commitment that can imply that it becomes optimal for responsible households to strictly engage in exit or boycott, but not both.

Figure 3 illustrates Proposition 1. It shows how the expected utility of individual responsible households depends on q_R and i_R (warm colors stand for high utility). The individual utility,

Figure 3: Expected Utility of Responsible Households



which neglects the marginal impact on the externality, is maximized at $\Delta i = \Delta q = 0$. If responsible households want to have an impact, they must deviate from this point towards the origin. For each impact level, the utility is maximized on the green line, given by $q_R^* = i_R^*/c$, and thus also by $\Delta q^* = \Delta i^*/c$.

Proposition 1 is an efficiency result, it describes the optimal combination of investment and consumption, not the levels. The optimal level is discussed in 4 and it depends on the motive of responsible households for their behavior. The motivation to move along the green line can have altruistic motives (agents internalize partially the externality), they might be able to coordinate actions within a group or they may assert peer pressure. We discuss the different motives and how they change the optimal levels in section 5.

3.1 The Optimal Combination with Heterogeneous Preferences.

A major simplification in our model is the assumption that households have homogeneous preferences. More realistically, the different types of household may also differ in their preferences for risk and consumption. [16] As preferences shape the market response to the responsible action, their heterogeneity could affect the optimal combination or responsible choices. We now analyze the aggregate effects of possible heterogeneity in preferences. We use indices for preference parameters: ρ_S is the risk aversion of standard households, ρ_R that of responsible households, etc. For a given consumption q_R and investment i_R of responsible households, prices and yields adjust so that standard households choose

$$\begin{aligned} q_S^* &= \frac{1}{b_S + c^2\,\rho_S\,\sigma^2}\left(a_S - c\,(r_f - \lambda) + c\,\gamma\,\rho_S\,\sigma^2\,\frac{i_R - c\,q_R}{1-\gamma}\right) \quad \text{and} \\ i_S^* &= \frac{c}{b_S + c^2\,\rho_S\,\sigma^2}\left(a_S - c\,(r_f - \lambda) - b_S\,\frac{\gamma}{c}\,\frac{i_R - c\,q_R}{1-\gamma}\right), \quad \text{so} \\ Q^* &= \frac{(1-\gamma)\,(a_S - c\,(r_f - \lambda)) + \gamma\,(b_S\,q_R + c\,\rho_S\,\sigma^2\,i_R)}{b_S + c^2\,\rho_S\,\sigma^2} \end{aligned}$$

and $I^* = c\,Q^*$. The first-order condition for responsible households yields

$$q_R^* = \frac{1}{(1-\gamma)\,\frac{b_R}{b_S} + 2\,\gamma}\left(\left((1-\gamma)\,\frac{\rho_R}{\rho_S} + 2\,\gamma\right)\frac{i_R^*}{c} + (1-\gamma)\,\frac{a_R - a_S}{b_S}\right). \tag{11}$$

This implies that for $a_R = a_S$, q_R^* and i_R^* are proportional. Proposition 1 is therefore robust for heterogeneities in risk eversion $\rho_R \neq \rho_S$, and in the product substitutability $b_R \neq b_S$.[17]

We focus on the impact of differences in product preferences and set $\rho_R = \rho_S$, and $b_R = b_S$ which simplifies (11) to

$$q_R^* = \frac{1}{c}\,i_R^* + \frac{1-\gamma}{1+\gamma}\,\frac{a_R - a_S}{b}. \tag{12}$$

If $a_R > a_S$ ($a_R < a_S$), then a constant is added to (subtracted from) consumption. This

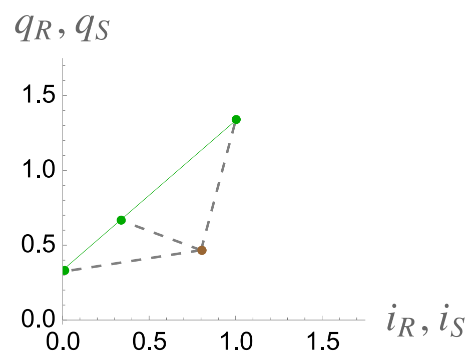
[16] Standard household can be interpreted as the global market investors and consumers that have better diversification opportunities, and therefore, smaller degrees of risk aversion. In addition, the dirty good might be a regional product. Standard households could then be interpreted as international consumers on the product market, caring less about consuming the good.

[17] We elaborate the impact of these heterogneities on the qualitatively similar results to Proposition 1 in Appendix B

implies that responsible households optimally lower their investment more (less) relative to the reduction in consumption to reach their target impact.

Due to preference heterogeneity, it is no longer optimal for responsible households to reduce i_R and q_R in the same proportion. If $a_R > a_S$, the investment should be reduced more than proportionally.

Figure 4: Expected Utility of Responsible Households, $a_R > a_S$



Parameters are $a_S = 1.5$, $a_R = 2$, and $\gamma = 50\%$, everything else as in Figure 2.

We illustrate this point in Figure 4, which shows the expected utility of responsible households with a stronger preference for the good $a_R = 2 > a_S = 1.5$. The individually utility-maximizing investment is $i_R^* = 1$, and consumption is at $q_R^* = 1.33$. Standard households invest about as much but consume considerably less. The aggregate investment is at $I^* = 0.9$, with an externality corresponding to it.

If responsible households efficiently reduce the externality, they follow (12). $\Delta i_R = c\,\Delta q_R$, but because investment was initially at a relatively low level, it is reduced more than proportionally. The product price is constant at

$$P = \frac{c}{b + c^2\,\rho\,\sigma^2}\left(b\,(r_f - \lambda) + c\,\rho\,\sigma^2\,\frac{a_S + \gamma\,a_R}{1+\gamma}\right),$$

also the expected return $r = P/c + \lambda$ does not change. Consequently, optimal responsible reduction does not change the standard households' choice of i_S^* and q_S^*.

At some point, responsible investment i_R^* has fallen to zero, but the consumption of responsible households q_R^* is still positive. This is not surprising: a large a_R means that responsible households like to consume the dirty product a lot. If responsible households want to achieve an even higher impact they can give up more of their highly valued consumption, while investment is fully avoided.

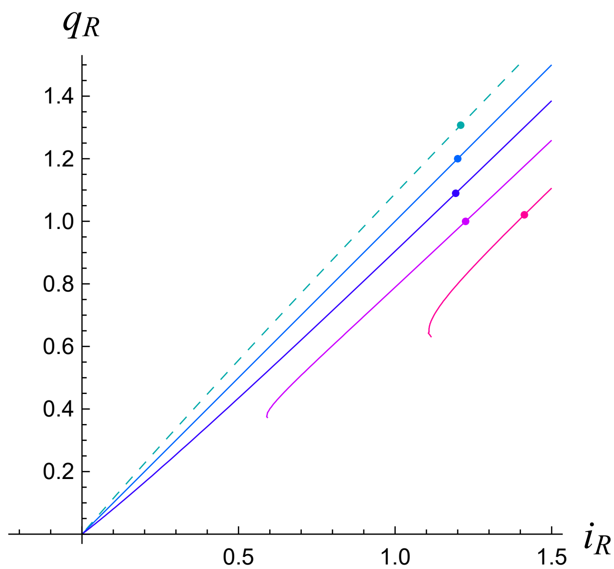
3.2 The Optimal Combination with Fixed Costs

Our assumption of a linear production function allows for explicit and tractable solutions. However, a non-linear production function would clearly impact the efficient combination of the two responsible margins. We therefore now assume that, to produce a quantity Q, an investment of $I_F + c\,Q$ is needed. This keeps our model tractable while allowing us to understand the impact of the shape of the production function on the optimal combination since any production function $Q(I)$ can be linearly approximated locally.

Pollution may stem from consumption or production, and the initial investment I_F may also cause emissions. The aggregate emissions will still be linear in Q, $X = X_0 + x\,Q$. The solution for the responsible households' optimization is still in closed form, but equations become rather messy, so let us turn to a simulation. Figure 5 shows the curves of the optimal combinations of q_R and i_R for different levels of fixed costs I_F. Points give the individually optimal levels.

We see that for $I_F = 0$, the efficient combination of q_R and i_R is a (blue) line through the origin, as stated in Proposition 1. It has a slope of $1/c$. For a fixed investment of $I_F = 0.1$ (deep purple), the efficient combination is a slightly convex curve. Starting from the individually optimal point, it is initially optimal to reduce consumption more than proportionally. The curve goes through the origin also for general parameter constellations. Therefore, on average, responsible households should reduce investment and consumption proportionally.

Figure 5: Impact of Fixed Costs



Parameters are $c = 1, \rho = 1/3, a = 2, b = 1/2, x = 1, \gamma = 1/2$, $\lambda = 0$, $\sigma = 1$ and $r_f = 1$. Furthermore, $I_F = 0.0$ (blue), $I_F = 0.1$ (deep purple), $I_F = 0.2$ (purple), and $I_F = 0.3$ (red). The dashed curve has $I_F = -0.1$.

For higher levels of fixed costs ($I_F = 0.2$, purple), there is an additional effect. If the responsible households do not invest ($i_R = 0$), the investment of the standard households is insufficient to cover the fixed costs. Consequently, the industry collapses, there is no investment, and there is no consumption. For $I_F = 0.3$ (red), the effect is even more pronounced. In the numerical example, we have not taken the liquidation values into account. Depending on the nature of the fixed costs, the resale value V may be relatively high. In that case, only the difference (net fixed costs) $I_F - V/r_f$ matters. It depends on the risk-free rate, and on the depreciation of the fixed asset. The effects of Figure 5 are mitigated accordingly.

Proposition 2 (Generalization of Proposition 1) *If the depreciation of fixed assets is negligible, it is efficient for responsible households to reduce investment and consumption proportionally, as in Proposition 1. If depreciation is noticeable, responsible households should reduce investment and consumption in proportion* on average. *For minor impact levels, they should reduce consumption more.*

We provide the formal proof in Appendix A. If depreciation is noticeable, responsible consumption is, then, relatively more effective for small levels of impact than responsible investment. For large levels of depreciation, if standard households cannot stem the net fixed costs on their own, responsible households can halt production by not investing.

4 The Optimal Impact

We now analyze how much responsible households would actually want to sacrifice and how they could commit to such a behavior. Responsible households differ from the standard households because they coordinate to implement the collectively optimal choice for themselves. The individual impact of each individual responsible household is infinitesimally small. By reducing consumption and investment, each household can only achieve a marginal impact on the externality, but suffers a discrete utility loss. Thus, it is rational from the individual perspective to neglect the negative externality. However, from a collective perspective, households can benefit from responsible behavior. They profit not only from their own infinitesimal impact, but also from that of other responsible households. The responsible household's willingness to sacrifice marginal utility therefore increases in the aggregate impact that responsible households are able to achieve.

Corollary 1 *To achieve an exogenous impact goal G, responsible households optimally sacrifice*

$$\Delta q = \min\left(\frac{G}{c\,\gamma}, q_0\right) \text{ and } \Delta i = \min\left(\frac{G}{\gamma}, I_0\right) \tag{13}$$

where $q_0 = \frac{a-c(r_f-\lambda)}{b+c^2\,\rho\,\sigma^2}$ and $I_0 = c\frac{a-c(r_f-\lambda)}{b+c^2\,\rho\,\sigma^2}$ define the optimal individual consumption and investment choices in the absence of responsible households, which constrain the feasible responsible choice.

The required sacrifice to reach a fixed goal decreases in the proportion of responsible households.[18] Fewer responsible households require higher individual responsible choices. If there are too few responsible households ($\gamma < \frac{G}{c\,(\varphi\, q_0+(1-\varphi)I_0)}$), the goal cannot be achieved even if all responsible households abstain completely from investment and consumption.

But what if responsible households can set their own goal? We assume that responsible households differ from standard households only because they are able to coordinate choices and thereby, at least partially, internalize the negative externality. Therefore, responsible households maximize their expected utility by taking into account the market responses of standard households, as well as the impact of their own choices on the externality.[19]

$$U_R = u\left(\underbrace{(w_0 - i_r)r_f + i_R\left(\frac{P^*(i_R, q_R)}{c} + \lambda + \varepsilon\right)}_{\text{Investment Payoff}} + \underbrace{aq_R - q_R P^*(i_R, q_R) - b\frac{q_R^2}{2}}_{\text{Consumption Return}} - \underbrace{x\, I^*(i_R, q_R)}_{\text{Externality}}\right) \tag{14}$$

where P^* and I^* are given in (7) and (9) respectively and with $q_R = q_0 - \Delta q$ and $i_R = i_0 - \Delta i$.

Proposition 3 (Coordinated Choices) *If $\gamma\, x \leq a/c - r_f$, responsible households optimally coordinate on*

$$\Delta q^* = c\,\frac{\gamma\, x}{b + \rho\,\sigma^2} \quad \textit{and} \quad \Delta i^* = c^2\,\frac{\gamma\, x}{b + \rho\,\sigma^2}. \tag{15}$$

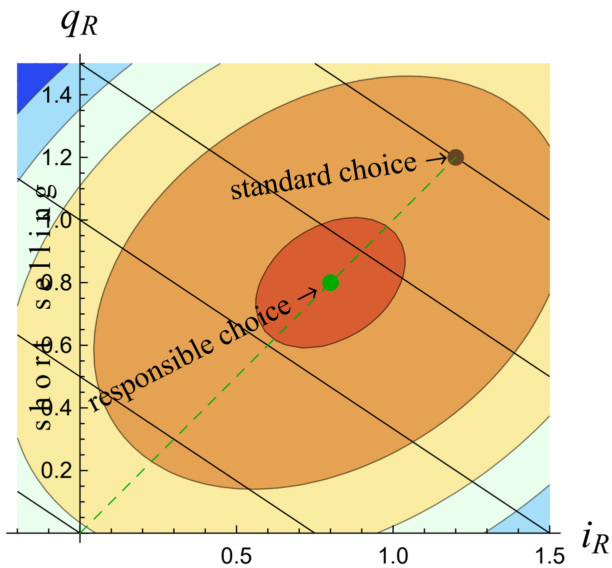
If $\gamma\, x > a/c - r_f$, responsible should households neither consume nor invest.

We illustrate the optimal responsible choice in Figure 6. In the figure, $\gamma = 1/3$ of households are responsible, and the externality is $x = 1$. If responsible households collectively reduce q_R

[18]An example of such a goal is the $1.5°C$ goal of the Paris Agreements.

[19]The infinitely small responsible households internalize the consequences of their actions either because they care about the direct consequences of their actions (consequentialism) or because they are able to coordinate as a group. Alternatively, we could assume that responsible households are altruistic, such that they value welfare in their utility. This would yield qualitatively similar results.

Figure 6: Expected Utility of Responsible Households, $\gamma = 1/3$, $x = 1$



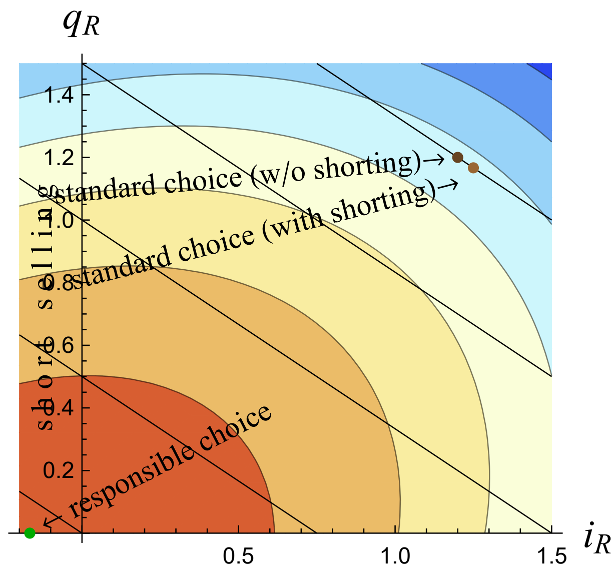
by Δq and i_R by Δi, they profit from the reduced externality. As shown in Proposition 1, it is efficient for responsible households to reduce investment and consumption proportionally.

An increase in the externality x or the fraction of responsible households moves the collectively optimal point towards the origin. For $\gamma\, x = a/c - r_f$, the origin is reached. For $\gamma\, x > a/c - r_f$, it is collectively optimal to consume nothing, $q_R^* = 0$, and (if possible) to short-sell shares,

$$i_S^* = -\frac{c\,(1-\gamma)\,(c\,(r_f + x\,\gamma) - a)}{b\,(c^2\,(1-\gamma) + 2\,\gamma) + c^2\,(1-\gamma)\,\rho\,\sigma^2} < 0.$$

With short selling, investment and consumption are obviously no longer reduced in proportion. Therefore, the responsible behavior now also affects the equilibrium price P. Standard households react by investing more and consuming less. Because standard households have reduced their consumption, the externality is further reduced. Figure 7 illustrates this: if consumption and investment are not reduced proportionally, the impact is relatively small. In the figure, the two brown points (with and without short-selling) are seemingly on the same iso-impact line.

Figure 7: Expected Utility of Responsible Households, $\gamma = 1/3$, $x = 11/3$



Social Welfare. If households coordinate on the optimal choice $(\Delta i^*, \Delta q^*)$, the obtained aggregate impact is

$$x\, \Delta I^*(\gamma) = \frac{\gamma^2\, c^2\, x^2}{b + c^2\, \rho\, \sigma^2} \tag{16}$$

which is increasing and convex in the proportion of responsible households γ. The impact per household increases in the fraction of responsible households so that each individual responsible household is also willing to forego more investment and consumption. If all households fully internalize the externality, $\gamma = 1$, they act like a social planer. The externality problem vanishes and aggregate social welfare becomes

$$W(1) = W_{\mathrm{FB}} = u\Big(\frac{(a - c\,(r_f - \lambda + x))^2}{2(b + \rho\, c^2\, \sigma^2)} + r_f\, w_0\Big). \tag{17}$$

On the contrary, without any responsible households $\gamma = 0$, the welfare obtained is

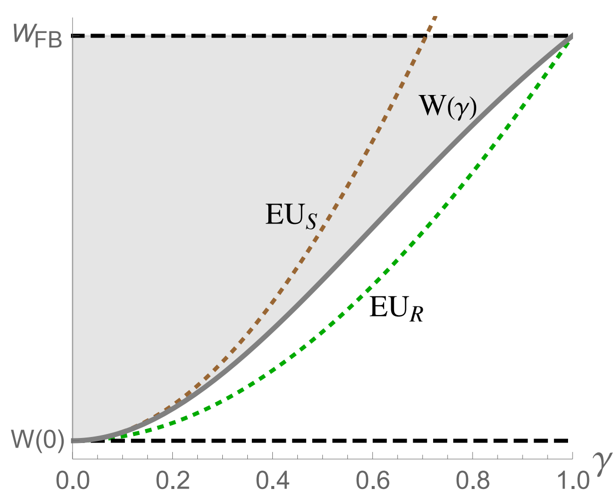
$$W(0) = u\Big(\frac{(a - c\,(r_f - \lambda + x))^2}{2(b + \rho\, c^2\, \sigma^2)} + r_f\, w_0 - \frac{1}{2}\frac{c^2\, x^2}{b + \rho\, c^2\, \sigma^2}\Big) \tag{18}$$

Households suffer in the aggregate because they do not price in the externality. Social welfare with a given proportion of responsible households equals the corresponding equilibrium level of aggregated utilities

$$W(\gamma) = \gamma \mathrm{E}U_R^*(\gamma) + (1-\gamma)\mathrm{E}U_S^*(\gamma) \quad \text{with} \tag{19}$$
$$\mathrm{E}U_R^*(\gamma) = u\Big(\frac{(a - c\,(r_f - \lambda + x))^2}{2(b + \rho\, c^2\, \sigma^2)} + r_f\, w_0 - \frac{1}{2}\frac{c^2\, x^2}{b + \rho\, c^2\, \sigma^2} + \frac{1}{2} x\, \Delta I^*(\gamma)\Big) \quad \text{and}$$
$$\mathrm{E}U_S^*(\gamma) = u\Big(\frac{(a - c\,(r_f - \lambda + x))^2}{2(b + \rho\, c^2\, \sigma^2)} + r_f\, w_0 - \frac{1}{2}\frac{c^2\, x^2}{b + \rho\, c^2\, \sigma^2} + x\, \Delta I^*(\gamma)\Big).$$

Coordination of responsible choices allows for an increase in aggregate social welfare, but this welfare gain is not equally distributed. Standard households gain more from the sacrifice $x\,\Delta I^*$ because they free-ride on the externality reduction without changing their optimal investment and consumption. Responsible households also gain from the coordinated choice but they have to sacrifice consumption and investment to reach this impact.

Figure 8: Social Welfare as a Function of Responsible Households γ, $x = 1$



We illustrate the social welfare gain of higher proportions of responsible households in Figure 8. The dashed lines represent the minimum $W(0)$ and maximum $W(1) = W_{FB}$ achievable social welfare. The gray area summarizes the social welfare losses due to the externality induced overproduction. The bold gray line depicts the social welfare $W(\gamma)$. Social welfare increases in the proportion γ of households acting responsibly. The responsible choice raises the individual utility of both responsible (dotted green line) and standard (dotted brown line) households. However, the gain in expected utility, however, is higher for standard households, who free-ride on the sacrifice of responsible households. If all households act responsibly, they implement the first-best social welfare.

5 Imperfect Commitment

Until now, we have simply assumed that responsible households can commit ex-ante to a desired consumption and investment level, but we did not discuss how. We now discuss possible commitment mechanisms and their impact on our results. For this we interpret responsible households as a subgroup that is able to coordinate on a commitment mechanism. We show that the optimal choicecan be implemented if taxation is costless in the sense that Tax revenues can be perfectly redistributed to responsible households. However, if responsible responsible households only have access to a dissipative tax, taxing consumption and investment becomes undesirable and the optimal choicecannot be implemented anymore. As the extreme case, we discuss the commitment of responsible behavior via peer-pressure costs that we call shame & blame. If commitment to responsible action can only be achieved by costly peer pressure, it becomes optimal to only focus on one margin instead of using both margins. In Section 5.3, we discuss the outcome if households can only credibly commit to a reduction in one market but not in the other. We show that such a one-sided commitment affects the equilibrium market prices and, therefore, yields empirical predictions.

5.1 Taxation

The γ responsible households can be interpreted as members of a country or some other political entity. They could then vote to implement Pigovian taxes τ_I on investment and

τ_Q on consumption. If there are no administrative costs, investment and consumption are perfectly observable and if taxes are completely redistributed to responsible households, the collectively optimal decision of Proposition 3 can be implemented.

For concreteness, assume that within the political entity, households pay $P + \tau_Q$ instead of P for the good. In addition, they only get a return of $P/c + \lambda - \tau_I$ instead of $P/c + \lambda$ outside the entity. The aggregate tax revenue is then $T = \tau_Q \, q_R + \tau_I \, i_R$, it is redistributed within the entity.

Proposition 4 *If a fraction γ of the population is subject to taxes τ_I on dirty investment and τ_Q on dirty consumption, and tax proceeds are redistributed within that group, then the social optimum for that group can be achieved by setting*

$$\tau_I = \frac{c^2 \, \rho \, \sigma^2}{b + c^2 \, \rho \, \sigma^2} \, \gamma \, x \quad \textit{and} \quad \tau_Q = c \, \frac{b}{b + c^2 \, \rho \, \sigma^2} \, \gamma \, x. \tag{20}$$

Comparing these values with those of (37), we see that the collectively optimal allocation is implemented by individually rational choices. There are several notable properties. Taxes are optimally proportional to the size of the externality x, but also to the size of the group. This is because of the externality: households outside the entity also profit from the reduction in the externality. If γ is small, the benefits accrue mostly outside of the entity. Second, if risk aversion or risk is small, only consumption should be taxed. A tax on investment would be futile, as standard investors would compensate for the reduction in investment. Symmetrically, if b is small, only investment should be taxed. Bringing the consumption tax and the investment tax on the same scale by dividing through c, the sum is an invariant, $\tau_Q/c + \tau_I = \gamma \, x$.

5.2 Shame & Blame

In the absence of political institutions, responsible households can also be interpreted as members of a social group of size γ. Due to their potential connection, members can observe the choices of others (e. g., through social networks). To reduce the externality, the members of the group can shame & blame each other for investing in the dirty industry or for the consumption of dirty goods. Assume that exerting shame & blame is free, but leads to a reduction in the utility of the blamed household by $\gamma\, g_I$ for each dollar invested and $\gamma\, g_C$ for each unit consumed.[20] It is equivalent to a tax that is not restituted to the group. Shame & blame, thus, directly affects the expected utility of each household, similar to a warm glow (see Andreoni, 1990) with a negative sign.

This constitutes a fundamental deviation from our benchmark setting. Until now, responsible households were assumed to have the same utility functions as standard households and only differ in their ability to coordinate their choices. Thus, free coordination and taxation allow households to reach the first-best welfare if all households act responsibly. In this section we assume responsible households cannot coordinate on the responsible choice itself. However, they can credibly commit to shaming & blaming each other to alter their utility functions. The rationale is to create additional costs of dirty investment and consumption. That way, responsible households are induced to consume and invest less. Instead of choosing responsible quantities, the social group can coordinate on penalties in the form of shame & blame. Because of the additional costs necessary to create commitment, the first-best social welfare (the investment and consumption amount chosen by a social planner) cannot be reached anymore even if all households act responsibly.[21]

[20] The factor γ expresses the fact that a larger group can exert more shame. The disutility can also be interpreted as a feeling of guilt. However, shame & blame can be chosen endogenously, while guilt, as part of the utility function, can be seen as exogenous.

[21] The outcome is the same as with responsible investors that have altruistic motives hard-wired into their utility functions. However, we focus on endogenous motives because we want to discuss optimal penalties. Shame & blame is a conceptual way out.

Without loss of generality, assume that the reduction in utility is proportional to γ. The rationale is that with an increasing social group size, the probability of being shamed or the intensity of the shame increases. The utility function of a responsible household becomes

$$U_R = u\big((w_0 - i_R)\, r_f + i_R\, r - q_R\, P + a\, q_R - b\, q_R^2/2 - x\, I - \gamma\, g_I\, i_R - \gamma\, g_C\, q_R\big). \tag{21}$$

The direct disutility from shame & blame is zero in two limiting cases. If $g_I = 0$ (or $g_C = 0$), households do not shame & blame each other for investing (consuming), and if $i_R = 0$ (or $q_R = 0$), responsible households abstain completely from dirty investment (consumption). Only in these extremes, shame & blame induces no direct costs. As responsible households gradually reduce their investment and consumption as in Proposition 3, shame & blame reduces the responsible households' utility. This additional reduction in utility creates a centrifugal force. These forces make any mix of SRI and SRC inefficient if households can only commit to responsible behavior by shaming and blaming each other. To see this, consider the product demand from responsible households,

$$q_R^* = \frac{a - P - \gamma\, g_C}{b}, \tag{22}$$

toned down due to disutility g_C. Similarly, the investment for a given share price is

$$i_R^* = \frac{P/c - r_f - \gamma\, g_I}{\rho\, \sigma^2}. \tag{23}$$

In combination with the market clearing conditions on the product market and the stock market, and the demand of standard households, we obtain an aggregate quantity

$$Q^* = \frac{a - c\,(r_f + \gamma^2\,(c\, g_I + g_C))}{b + c^2\, \rho\, \sigma^2}. \tag{24}$$

The disutility of investment g_I and consumption g_C has an identical effect on aggregate production Q^*. If ρ is low, an increase in g_I has a strong effect on investment by responsible households i_R^*, but the standard households are also more willing to substitute by investing more. The role of risk aversion is canceled out. The same holds for larger b.

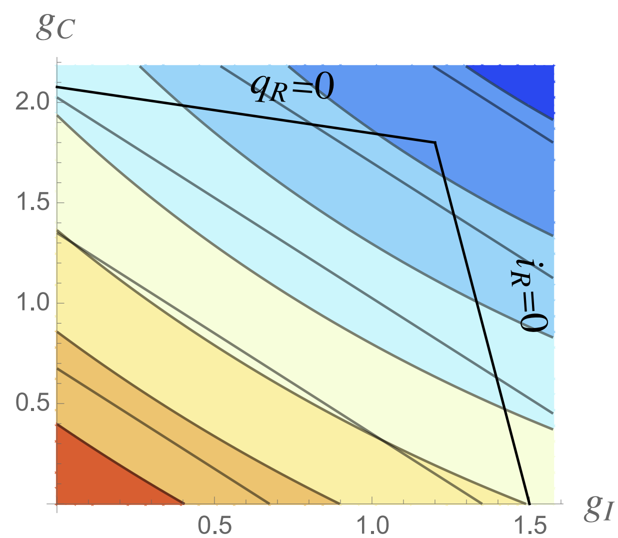
However, the disutility created from shame & blame has an important implication for the optimal individual choice. As households can no longer choose the actual investment and consumption quantities, but only the additional costs g_I and g_C, the nature of the optimization problem changes. The expected utility of responsible households, which is concave in investment and consumption amounts, is convex in the shaming cost factors as we prove in Appendix A. For a given target impact on the externality, the utility-maximizing choice of shame therefore becomes a corner solution.

In contrast to Proposition 1 it is no longer optimal to commit to a proportional reduction in investment and consumption. Instead, responsible households focus on *either* investment or consumption reduction. For small impact levels, the optimal shame & blame strategy focuses either on reducing investment (by an increase in g_I), or on reducing consumption (by an increase in g_C), but not both. For large impact levels, it consists of either $q_R = 0$ or $i_R = 0$, and a reduction of the other amount. The rationale is the mentioned centrifugal force due to the direct disutility induced by guilt.

Figure 9 shows the iso-impact lines as black diagonals. Each line has a slope of -1. The impact is lowest at the origin and increases towards the north-east. The figure also shows the expected utility of responsible households, depending on the disutility of investment g_I and of consumption g_C. In the numerical example, for $g_I = 1.2$, investment i_R by responsible households becomes zero. For $g_C = 1.8$, consumption q_R becomes zero. Increasing g_I or g_C above these levels does not have additional impact.

Also the insights from Proposition 3 change. Collectively, the optimal choice does not depend continuously on the fraction γ and the externality x. The optimal shame & blame policy is binary. For low levels of γ and x, it is optimal to do nothing and set $g_I = g_C = 0$. At

Figure 9: Expected Utility of Responsible Households with Shame & Blame



the point $2\,\gamma\, x = a/c - r_f$, it becomes optimal to set g_I and g_C at a level that *completely* prevents responsible households from dirty investment and dirty consumption. In a sense, the choice of responsible households is always extreme. Either they behave like standard households (for $2\,\gamma\, x < a/c - r_f$), or they neither invest nor consume (for $2\,\gamma\, x > a/c - r_f$). In the second case, they shame & blame one another, but because they neither invest nor consume, this does not create any direct disutility.

The size of the group becomes crucial for the socially optimal choice. If the group size is too small, given the externality, responsible households do not want to coordinate on reducing the externality. If the group size is large enough, responsible households will credibly commit to reduce the externality without any direct disutility from shaming and blaming. Coordination implies a commitment on a shame & blame threat that deters any dirty investment or consumption of the group members.

5.3 One-sided Coordination

Coordination could be more feasible in one market than in the other. On the one hand, investing in a green fund might offer a natural way to coordinate SRI. However, the individual investment decision is difficult to observe. Consumption behavior, on the other hand, could be easily observed, so peer pressure-based coordination might be more feasible for SRC. Our model implies testable empirical implications for the case where households can better coordinate in one market than in the other.

The Clean Benchmark. Let us define a clean benchmark, to analyze how market prices of dirty goods and dirty investment yields are affected by the imperfectly coordinated choices of responsible households. Consider a benchmark economy with identical consumer preferences and a continuum of firms with identical risk and product characteristics. However, the "clean" benchmark firms and products do not cause any externality $x = 0$. Consequently, the optimal choice of γ responsible households is $\Delta q = 0$ and $\Delta i = 0$ (see Proposition 3). For a clean firm, that does not produce any negative externality, the responsible investment and consumption choice does not differ from the optimal choice of standard households $i_R|_{x=0} = i_S|_{\gamma=0}$ and $q_R|_{x=0} = q_S|_{\gamma=0}$. Ceteris paribus, the resulting equilibrium quantities and prices therefore equal those of the dirty firms in the absence of responsible households (if $\gamma = 0$) as defined in Appendix A. The expected equilibrium return for a clean investment ($x = 0$) is therefore

$$E[r_0] = \frac{c\,\rho\,\sigma^2\,(a + c\,\lambda) + b\,r_f}{b + c^2\,\rho\,\sigma^2}. \tag{25}$$

The equilibrium price for the clean good is

$$P_0 = \frac{c}{b + \rho\,c^2\,\sigma^2}\,\big(c\,\rho\,\sigma^2\,a\, + b\,(r_f - \lambda)\big). \tag{26}$$

Note that Proposition 1 implies that, while the optimal responsible choice decreases production and investment and thus the externality, prices and yields remain unchanged. In other words, as long as responsible households are able to coordinate in both markets, ceteris paribus, clean and dirty investment yields and product prices should be the same, while fewer dirty products are produced.

Commitment only to Responsible Consumption. Responsible households might only be able to commit to consume responsibly $\Delta q > 0$ but not to a reduction in investment. We use (7) and (8) to derive the implications of household behavior and obtain

$$P = P_0 - \gamma \frac{b\, c^2\, \rho\, \sigma^2}{b + c^2\, \rho\, \sigma^2}\, \Delta q \quad \text{and} \tag{27}$$

$$E[r] = E[r_0] - \gamma \frac{b\, c\, \rho\, \sigma^2}{b + c^2\, \rho\, \sigma^2}\, \Delta q. \tag{28}$$

Proposition 5 *If responsible households can commit to SRC, but fail to commit to SRI, the reduction of consumption (increased Δq) decreases the investments yield of dirty investments compared to the clean benchmark $E[r_0]$.*

One-sided consumption boycott decreases investment yields and market prices. In response, standard households consume more, but invest less than in the absence of responsible households.

Commitment only to Responsible Investment. The opposite occurs if households can only commit to a reduction of the dirty investment. We then obtain

$$P = P_0 + \gamma \frac{b\, c\, \rho\, \sigma^2}{b + c^2\, \rho\, \sigma^2}\, \Delta i \quad \text{and} \tag{29}$$

$$E[r] = E[r_0] + \gamma \frac{b\, \rho\, \sigma^2}{b + c^2\, \rho\, \sigma^2}\, \Delta i. \tag{30}$$

Proposition 6 *If responsible households can commit to SRI, but fail to commit on SRC, the reduction of investment (increased Δi) increases the investments yield of dirty investments compared to the clean benchmark $E[r_0]$.*

The expected return of the dirty investment increases in equilibrium, as does the price of the dirty good. Standard households therefore invest more but consume less than in the absence of responsible households. Propositions 5 and 6 imply opposing empirical predictions depending on the ability of households to coordinate on responsible behavior. This may help explain why empirical papers obtain contradictory results on the relative performance of green investments over time and in different countries.

6 Conclusion

Ethical concerns are increasingly important to retail investors. However, investment, production, and consumption decisions are intertwined and should not be studied separately. We raise the question of whether household investors should worry about ethics when investing money. Alternatively, households could focus on more sustainable consumption. We develop a tractable closed microeconomic model with interlinked capital and goods markets that allows us to analyze the optimal choice of responsible households. We show that responsible concerns matter, regardless of whether they occur when investing (socially responsible investment, SRI, exit) or when consuming (socially responsible consumption, SRC, boycott) as long as standard households ("the others") are risk averse and find it difficult to replace the dirty good. However, to achieve the greatest impact at the lowest possible utility loss, responsible households must reduce their dirty consumption proportionally to their divestment from dirty firms (Proposition 1). A disproportional reduction would be substituted for by other market participants, at least partially, and is therefore suboptimal. If responsible households can coordinate, their commitment to proportional consumption and investment reduction increases with the size of the externality and with their group size. The proportionality implies that the responsible investment exit and product boycott leave the equilibrium product prices and capital returns unchanged.

We have assumed that production and consumption come with a negative externality. However, the formalism also holds for the opposite sign. Hence, if the product bears a positive externality, responsible households should increase their consumption and investment by the same factor. A green financial strategy should then also be part of responsible households' behavior. They should divest from dirty industries and overinvest in clean industries.

There are many open questions that can be addressed with extensions of this stylized model. First of all, one can construct a carbon footprint calculator (or, more generally, an externality-footprint calculator) that takes financial decisions into account. Current calculators only look at consumption decisions. The symmetry between investment and consumption in the model suggests that such calculators overestimate the impact of consumption choices, and underestimate that of investment choices. Second, we have assumed perfect competition and perfect financial markets. We want to introduce a capital structure of firms, and potentially also financial frictions to assess the desirability of different security classes from the perspective of the externality. Third, we have assumed exponential utility functions, which means that initial endowments of households are irrelevant. We want to change this assumption to talk about distributional effects. Fourth, and importantly, our model contains only one interesting industry, the polluting industry, and "everything else". We can easily adapt the model to multiple industries, allowing for complements and substitutes on both the product and the financial market (correlations). In that case, there can be several indirect effects. For example, if a households consume less from a polluting good A, other households might consume more of it, and then consume less of another, possibly less polluting, substitute. There are also important complementarities, like "buying a car" and "driving around in a car". Fifth, our industry needs consumers and investors. One could extend the model by labor, and a labor choice. That way, a household could ask: "If I want to have an efficient impact, should I stop consuming polluting goods, should I stop investing in polluting firms, or should I stop working for polluting companies?" Sixth, other input factors, such as oil/gas or rare earths, can also be implemented. This is helpful to assess optimal policies of whole countries that not only focus on their consumers but also indirect pollution from their industries. Our model could then elicit the question what a country that exports dirty input factors should optimally do? Is it effective to continue exporting and choose a green financial strategy?

A Proofs

Proof of Lemma 1: The equilibrium for a given responsible investment i_R and consumption level q_R is defined by the following system of equations

$$\frac{\partial \mathrm{E} U_S}{\partial q_S} = \big(P - (a - b\, q_S)\big)\rho = 0, \tag{31}$$

$$\frac{\partial \mathrm{E} U_S}{\partial i_S} = \big(r_f - \lambda + i_S\, \rho\, \sigma^2 - \frac{P\,Q}{I}\big) = 0,$$

$$I = \gamma\, i_R + (1-\gamma)\, i_S,$$

$$Q = \gamma\, q_R + (1-\gamma)\, q_S, \tag{32}$$

$$Q = {}^{I}\!/_{c}. \tag{33}$$

Using $Q = {}^{I}\!/_{c}$, the first order condition with respect to i_S yields

$$i_S^* = \frac{P/c + \lambda - r_f}{\rho\, \sigma^2}. \tag{34}$$

In the aggregate, the capital market must clear:

$$I^* = \gamma\, i_R + (1-\gamma)\, \frac{P/c + \lambda - r_f}{\rho\, \sigma^2}. \tag{35}$$

Substituting the aggregate demand (32) and $I^* = c\,Q^*$ we obtain the equilibrium quantity

$$Q^* = \frac{(1-\gamma)\,(a - c\,(r_f - \lambda)) + \gamma\,(b\,q_R + c^2\,\rho\,\sigma^2\,{}^{i_R}\!/\!{}_c)}{b + c^2\,\rho\,\sigma^2}. \tag{36}$$

the equilibrium investment is $I^* = c\,Q^*$ the equilibrium prices are given by

$$P^* = \frac{c^2\,\rho\,\sigma^2\,a\ + b\,c\,(r_f - \lambda)}{b + \rho\,c^2\,\sigma^2} + \frac{\gamma}{1-\gamma}\,\frac{b\,c^2\,\rho\,\sigma^2}{(b + c^2\,\rho\,\sigma^2)}\,\big(q_R - {}^{i_R}\!/\!{}_c\big) \quad \text{and}$$
$$E[r]^* = \frac{c\,\rho\,\sigma^2\,(a + c\,\lambda) + b\,r_f}{b + c^2\,\rho\,\sigma^2} + \frac{\gamma}{1-\gamma}\,\frac{b\,c\,\rho\,\sigma^2}{b + c^2\,\rho\,\sigma^2}\,\big(q_R - {}^{i_R}\!/\!{}_c\big).$$

The equilibrium investment and consumption choices of standard households are

$$i_S^* = \frac{c}{b + c^2\,\rho\,\sigma^2}\,\Big(a - c\,(r_f - \lambda) + \gamma\,b\,\frac{q_R - {}^{i_R}\!/\!{}_c}{1-\gamma}\Big) \quad \text{and thus}$$
$$q_S^* = \frac{1}{b + c^2\,\rho\,\sigma^2}\,\Big(a - c\,(r_f - \lambda) - \gamma\,c^2\,\rho\,\sigma^2\,\frac{q_R - {}^{i_R}\!/\!{}_c}{1-\gamma}\Big). \tag{37}$$

We see that, if responsible households consume (invest) less, standard households react by consuming more (less) and investing less (more). Defining $q_R = q_0 - \Delta q$ and $i_R = i_0 - \Delta i$, the optimal choice of standard households absent any responsible households minus the responsible exit Δi and boycott Δq. The equilibrium quantity absent responsible households is

$$q_0 = Q_0 = \frac{a - c\,(r_f - \lambda)}{b + c^2\,\rho\,\sigma^2}$$

and $i_0 I_0 = c\,Q_0$ accordingly. The expected equilibrium return is

$$E[r_0] = \frac{c\,\rho\,\sigma^2\,(a + c\,\lambda) + b\,r_f}{b + c^2\,\rho\,\sigma^2}. \tag{38}$$

The equilibrium price is

$$P_0 = \frac{c}{b + \rho\,c^2\,\sigma^2}\,\big(c\,\rho\,\sigma^2\,a\ + b\,(r_f - \lambda)\big). \tag{39}$$

Using the standard economy (γ_0) as a benchmark equilibrium, we can characterize the equilibrium in terms of the impact of boycott Δq and exit Δi

$$
\begin{aligned}
q_S &= q_0 - \gamma \frac{c^2 \rho \, \sigma^2}{b + c^2 \, \rho \, \sigma^2} (\Delta q - {}^{\Delta i}\!/_{c}) \\
i_S &= i_0 - \gamma \, c \frac{b}{b + c^2 \, \rho \, \sigma^2} \, (\Delta q - {}^{\Delta i}\!/_{c}) \\
Q &= Q_0 - \gamma \frac{(b \, \Delta q + c^2 \rho \, \sigma^2 \, {}^{\Delta i}\!/_{c})}{b + c^2 \, \rho \, \sigma^2} \\
I &= I_0 - \gamma \, c \frac{(b \, \Delta q + c^2 \rho \, \sigma^2 \, {}^{\Delta i}\!/_{c})}{b + c^2 \, \rho \, \sigma^2} \\
P &= P_0 - \gamma \frac{b \, c^2 \, \rho \, \sigma^2 \, (\Delta q - {}^{\Delta i}\!/_{c})}{b + c^2 \, \rho \, \sigma^2}.
\end{aligned}
$$

Using equation (9) we can write the aggregate impact of responsible choices as

$$
\begin{aligned}
x \Delta I(\Delta i, \Delta q) &= x(\gamma \, c \, (\varphi \, \Delta q + (1 - \varphi) \, {}^{\Delta i}\!/_{c}), \quad \text{and} \\
\mathrm{MRT}_{\Delta i, \Delta q} &= -\frac{\partial x \Delta I}{\partial \Delta i} \Big/ \frac{\partial x \Delta I}{\partial \Delta q} = -\frac{{}^{(1-\varphi)}\!/_{c}}{\varphi} = -\frac{c \, \rho \, \sigma^2}{b}.
\end{aligned}
$$

which is the marginal rate of transformation for impact creation. ■

Proof of Proposition 1: The idea of the proof is in Figure 3. The slope of the diagonal iso-impact lines (Lemma 1) is $\frac{di_R}{dq_R} = -c \, \rho \, \sigma^2 / b$. The implicit function theorem gives the slope of the iso-utility curves as

$$
\frac{\frac{\partial \mathrm{E} \, U_R}{\partial i_R}}{\frac{\partial \mathrm{E} \, U_R}{\partial q_R}} = -\frac{\rho \, \sigma^2}{b} \, \frac{b \, ((1 + \gamma) \, i_R - 2 \, c \, q_R \, \gamma) - c \, (1 - \gamma) \, (a - c \, (r_f - \lambda - x \, \gamma + \rho \, \sigma^2 \, i_R))}{\rho \, \sigma^2 \, c \, (c \, q_R \, (1 + \gamma) - 2 \, i_R \, \gamma) - (1 - \gamma) \, (a - b \, q_R - c \, (r_f - \lambda + x \, \gamma))}. \tag{40}
$$

The utility function is a positive monotonic transformation of a quadratic function with the Hessian matrix

$$
H = \begin{pmatrix} -\rho^2 \, \sigma^2 \, \frac{b \, (1+\gamma) + c^2 \, (1-\gamma) \, \rho \, \sigma^2}{(1-\gamma)(b + c^2 \, \rho \, \sigma^2)} & \frac{2 \, b \, c \, \gamma \, \rho^2 \, \sigma^2}{(1-\gamma)(b + c^2 \, \rho \, \sigma^2)} \\ \frac{2 \, b \, c \, \gamma \, \rho^2 \, \sigma^2}{(1-\gamma)(b + c^2 \, \rho \, \sigma^2)} & -b \, \rho \, \frac{b \, (1-\gamma) + c^2 \, (1+\gamma) \, \rho \, \sigma^2}{(1-\gamma)(b + c^2 \, \rho \, \sigma^2)} \end{pmatrix}.
$$

The determinant is

$$\frac{b\,(1+\gamma)\,\rho^3\,\sigma^2}{1-\gamma}.$$

Hence the matrix is negative definite, hence each iso-impact line touches an iso-utility curve at one unique point, and this point is the optimum. Entering $i_R = c\,q_R$ into (40) gives a slope of $-c\,\rho\,\sigma^2/b$, which is identical to the slope of the iso-impact lines. This proves that the optimum satisfies $i_R = c\,q_R$. Because also $I_0 = c\,Q_0$, consequently $\Delta i = c\,\Delta q$. Note that one could have used Lagrange multipliers. This would have lead to algebraically intractable equations, with the same outcome. ■

Proof of Proposition 3: The derivative of (14) with respect to i_R and q_R yields

$$\frac{\partial \mathrm{E}U_R}{\partial q_R} = \rho\, b\, \frac{(1-\gamma)(b\,q_R - a + c(r_f - \lambda + x\,\gamma)) + c\,\rho\,\sigma^2\,(c\,q_R\,(1+\gamma) - 2\,i_R\gamma)}{(1-\gamma)(b + c^2\,\rho\,\sigma^2)} = 0 \tag{41}$$

$$\frac{\partial \mathrm{E}U_R}{\partial i_R} = \rho\,\sigma\, \frac{(1-\gamma)(\rho\,c^2\,\sigma^2\,i_R - a\,c + c^2\,(r_f - \lambda + x\,\gamma)) + b\,(i_R(1+\gamma) - 2\,c\,q_R\,\gamma))}{(1-\gamma)(b + c^2\,\rho\,\sigma^2)} = 0 \tag{42}$$

Solving (41) for q_R we obtain

$$q_R(i_R) = \frac{(1-\gamma)(a - c(r_f - \lambda + x\,\gamma)) + 2\,i_R\gamma\,c\,\rho\,\sigma^2}{(1-\gamma)b + (1+\gamma)\rho\,c^2\,\sigma^2} \tag{43}$$

Inserting (43) into (42) we obtain

$$\frac{(1+\gamma)\,\rho\,\sigma(b\,i_R - \ a\,c + c^2\,(r_f - \lambda + x\,\gamma) + r_R\,\rho\,c^2\sigma^2)}{b(1-\gamma) + (1+\gamma)\rho\,c^2\,\sigma^2)} = 0. \tag{44}$$

Solving (44) for i_R^* and $q_R^* = q_R(i_R^*)$ we obtain the optimal investment and consumption quantities of responsible households,

$$q_R^* = \frac{a - c\,(r_f - \lambda + \gamma\,x)}{b + \rho\,\sigma^2} \quad \text{and} \quad i_R^* = c\,\frac{a - c\,(r_f - \lambda + \gamma\,x)}{b + \rho\,\sigma^2}. \tag{45}$$

Subtracting the responsible choice from the standard choice $\Delta i = i_0^* - i_R^*$ and $\Delta q = q_0^* - q_R^*$, we obtain the optimal responsible choice as displayed in Proposition 3. ■

Proof of Proposition 4: Consider a global economy that consists of two entities. The entity $1-\gamma$ consists of standard households that do not want to introduce any tax. The responsible entity consists of γ households that opt for the implementation of an Pigovian tax τ_I and τ_Q. Within the responsible entity, households pay a price $P + \tau_Q$ and get an expected return $P/c + \lambda - \tau_I$. The aggregate tax revenue is $T = \tau_Q q_R + \tau_I i_R$ and it is redistributed within the entity. The utility of the (otherwise standard) households in the responsible entity is now defined as

$$\mathrm{E}U_R = -e^{-\rho\,(a\,q_R - b\,q_R^2/2 - (P+\tau_Q)\,q_R + (w_0 - i_R)\,r_f + i_R\,((P+\tau_Q)/c + \lambda - \tau_I - i_R\,\rho\,\sigma^2/2) - x\,I + T\big)}. \tag{46}$$

Given the Pigovian tax, the equilibrium is defined by the following systems of equations

$$\frac{\partial \mathrm{E}U_S}{\partial q_S} = \big(P - (a - b\,q_S)\big)\rho = 0, \tag{47}$$

$$\frac{\partial \mathrm{E}U_S}{\partial i_S} = \big(r_f - \lambda + i_S\,\rho\,\sigma^2 - \frac{P\,Q}{I}\big) = 0,$$

$$\frac{\partial \mathrm{E}U_R}{\partial q_R} = \big(P + \tau_Q - (a - b\,q_R)\big)\rho = 0 \tag{48}$$

$$\frac{\partial \mathrm{E}U_R}{\partial i_R} = \big(r_f + \tau_I - \lambda + i_R\,\rho\,\sigma^2 - \frac{P\,Q}{I}\big) = 0$$

$$I = \gamma\, i_R + (1-\gamma)\, i_S$$

$$Q = \gamma\, q_R + (1-\gamma)\, q_S \tag{49}$$

$$Q = {}^{I}\!/_{c} \tag{50}$$

Using $Q = {}^{I}\!/_{c}$, the first order condition with respect to i_S and i_R yields

$$i_S^* = \frac{P/c + \lambda - r_f}{\rho\,\sigma^2} \quad \text{and} \quad i_R^* = \frac{P/c + \lambda - r_f - \tau_I}{\rho\,\sigma^2}. \tag{51}$$

In the aggregate, the capital market must clear:

$$I^* = \frac{P/c + \lambda - r_f}{\rho\,\sigma^2} - \gamma\frac{\tau_I}{\rho\,\sigma^2}. \tag{52}$$

The product market clearing price (7) now becomes

$$P^* = a - b\,Q - \gamma\,\tau_Q \tag{53}$$

Substituting the price and $I = c\,Q$ we obtain the equilibrium quantity

$$Q^* = \frac{a - c\,(r_f - \lambda) - \gamma\,(\tau_Q + c\,\tau_I)}{b + c^2\,\rho\,\sigma^2}. \tag{54}$$

Equilibrium investment is $I^* = c\,Q^*$ and the equilibrium price is

$$P^* = \frac{c}{b + c^2\,\rho\,\sigma^2}\Big(c\,\rho\,\sigma^2(a - \gamma\,\tau_Q) + b(r_f - \lambda - \gamma\,\tau_I)\Big). \tag{55}$$

The individually rational choice outside the responsible entity becomes

$$\begin{aligned} i_S^* &= \frac{c}{b + c^2\,\rho\,\sigma^2}\left(a - c\,(r_f - \lambda) + \gamma\,\frac{b\,\tau_I - c\,\rho\,\sigma^2\,\tau_Q}{c\,\rho\,\sigma^2}\right), \\ q_S^* &= \frac{1}{b + c^2\,\rho\,\sigma^2}\left(a - c\,(r_f - \lambda) - \gamma\,c\,\frac{b\,\tau_I - c\,\rho\,\sigma^2\,\tau_Q}{b}\right). \end{aligned} \tag{56}$$

Within the responsible entity, households choose

$$\begin{aligned} i_R^* &= \frac{c}{b + c^2\,\rho\,\sigma^2}\left(a - c\,(r_f - \lambda) + \gamma\,\frac{b\,\tau_I - c\,\rho\,\sigma^2\,\tau_Q}{c\,\rho\,\sigma^2}\right) - \frac{\tau_I}{\rho\,\sigma^2}, \\ q_R^* &= \frac{1}{b + c^2\,\rho\,\sigma^2}\left(a - c\,(r_f - \lambda) - \gamma\,c\,\frac{b\,\tau_I - c\,\rho\,\sigma^2\,\tau_Q}{b}\right) - \frac{\tau_Q}{b}. \end{aligned} \tag{57}$$

Equating the responsible choices under taxation with the optimal choices in Proposition (3) we obtain the taxation as displayed in Proposition (4). ■

Proofs for Section 5.2 (Shame & Blame): In the absence of free coordination, responsible households cannot credibly commit to a certain investment or consumption amount. Instead, the equilibrium outcomes become a function of the shame costs g_C and g_I. Given these costs, the equilibrium is defined as

$$
\begin{aligned}
i_S &= c\,\frac{a - c\left(r_f + \gamma^2\left(g_C - g_I\frac{b}{\rho\,\sigma^2}\right)\right)}{b + \rho\sigma^2},\\
q_S &= \frac{a - c\left(r_f + \gamma^2\left(g_I - g_C\frac{\rho\,\sigma^2}{b}\right)\right)}{b + \rho\sigma^2},\\
i_R &= i_S - c\,\gamma\,\frac{c}{\rho\,\sigma^2}\,g_I,\\
q_R &= q_S - \gamma\,\frac{c}{b}\,g_C, \quad \text{resulting in}\\
Q &= \frac{a - c\,(r_f + (\gamma^2\,(g_I + g_C)))}{b + \rho\,\sigma^2}.
\end{aligned}
$$

The slope of the diagonal iso-impact lines is $\frac{dg_I}{dg_C} = -1$. Increasing the shame has an identical impact on the externality for each choice. The implicit function theorem gives the slope of the iso-utility curves as

$$
-\frac{\frac{\partial \mathrm{E}\,U_R}{\partial g_I}}{\frac{\partial \mathrm{E}\,U_R}{\partial g_C}} = -\frac{b\,(\rho\,\sigma^2(c(\gamma((2-\gamma)\gamma g_C + g_I + x) + r_f) - a) + bc\gamma(1-\gamma)^2 g_I)}{\rho\,\sigma^2\,(-ab + bc(\gamma(g_C + (2-\gamma)\gamma g_I + x) + r_f) + c(1-\gamma)^2\gamma g_C\,\rho\,\sigma^2)}. \tag{58}
$$

The utility function is positive monotonic transformation of a quadratic with the Hessian

$$
H = \begin{pmatrix} \frac{c^2\gamma^2\left(b(1-\gamma)^2 + \rho\,\sigma^2\right)}{\sigma^2(b+\rho\,\sigma^2)} & -\frac{c^2(2-\gamma)\gamma^3\rho}{b+\rho\sigma^2} \\ -\frac{c^2(2-\gamma)\gamma^3\rho}{b+\rho\,\sigma^2} & \frac{c^2\gamma^2\rho\left(b + (1-\gamma)^2\rho\,\sigma^2\right)}{b(b+\rho\,\sigma^2)} \end{pmatrix}.
$$

The determinant has the main factor $\frac{c^4(1-\gamma)^2\gamma^4\rho}{b\sigma^2}$. Hence, the matrix is positive definite such that the iso-impact line touches an iso-utility curve at the two corners, and one of the corner solutions is the optimum. ■

Proofs of Propositions 5 and 6: First consider the case in which responsible households can only coordinate on boycotting consumption. Their optimal investment choice is the same as the standard households $i_R = i_S$. The equilibrium for a given responsible consumption level q_R is defined by the following system of equations

$$\begin{aligned}
\frac{\partial \mathrm{E}U_S}{\partial q_S} &= \big(P - (a - b\,q_S)\big)\rho = 0,\\
\frac{\partial \mathrm{E}U_S}{\partial i_S} &= \big(r_f - \lambda + i_S\,\rho\,\sigma^2 - \frac{P\,Q}{I}\big) = 0,\\
I &= i_S,\\
Q &= \gamma\,q_R + (1-\gamma)\,q_S,\\
Q &= {}^{I}\!/_{c}.
\end{aligned}$$

Using $Q = {}^{I}\!/_{c}$, the first order condition with respect to i_S yields

$$i_S^* = \frac{P/c + \lambda - r_f}{\rho\,\sigma^2}. \tag{59}$$

This must also hold in the aggregate (capital market clears)

$$I^* = \frac{P/c + \lambda - r_f}{\rho\,\sigma^2}. \tag{60}$$

Substituting the aggregate demand and $I = c\,Q$ we obtain the equilibrium quantity

$$Q^* = \frac{(1-\gamma)a - c(r_f - \lambda) + \gamma\,b\,q_R}{b + (1-\gamma)c^2\,\rho\,\sigma^2} \tag{61}$$

The optimal investment of all households

$$i_S^* = c\frac{(1-\gamma)(a - c\,(r_f - \lambda)) + \gamma\,b\,q_R}{b + (1-\gamma)\,c^2\,\rho\,\sigma^2}\,, \tag{62}$$

which also equals the aggregate equilibrium investment $I^* = c\,Q^*$. The standard household's optimal consumption is

$$q_S^* = \frac{(1-\gamma)(a - c\,(r_f - \lambda)) + \gamma\, c\, \rho\, \sigma^2\, q_R}{b + (1-\gamma)\, c^2\, \rho\, \sigma^2}\,. \tag{63}$$

The resulting equilibrium price is

$$P^* = c\frac{(1-\gamma)c^2\, \rho\, \sigma^2\, a\; + b\, c\,(r_f - \lambda)\; + \gamma\, b\, c^2\, \rho\, \sigma^2\, q_R}{(b + (1-\gamma)\, c^2\, \rho\, \sigma^2)}. \tag{64}$$

The expected equilibrium return is

$$E[r^*] = \frac{(1-\gamma)c\, \rho\, \sigma^2\, (a + c\,\lambda) + b\, r_f + \gamma\, b\, c\, \rho\, \sigma^2\, q_R}{b + (1-\gamma)\, c^2\, \rho\, \sigma^2}. \tag{65}$$

Using the clean benchmark P_0 and $E[r_0]$ we can write

$$\begin{aligned} P^* &= P_0 - \gamma\, \frac{b\, c^2\, \rho\, \sigma^2}{b + (1-\gamma)\, c^2\, \rho\, \sigma^2} \left(\frac{a - c(r_f - \lambda)}{b + c^2\, \rho\, \sigma^2} - q_R \right) \quad \text{and} \\ E[r^*] &= E[r_0] - \gamma\, \frac{b\, c\, \rho\, \sigma^2}{b + (1-\gamma)\, c^2\, \rho\, \sigma^2} \left(\frac{a - c(r_f - \lambda)}{b + c^2\, \rho\, \sigma^2} - q_R \right). \end{aligned}$$

Substituting $q_R = q_S^*(0) - \Delta q$, where $q_S^*(0) = \frac{a - c(r_f - \lambda)}{b + c^2 \rho \sigma^2}$ is the amount a standard household would consume absent any responsible action as defined earlier, we get the yields as functions of the responsible deviation Δq as given in (27) and (28). An increased sole consumer boycott increases product prices and investment returns compared to the clean benchmark,

$$\begin{aligned} \frac{\partial (P^* - P_0)}{\partial \Delta q} &= \gamma,\frac{b\, c^2\, \rho\, \sigma^2}{b + (1-\gamma)\, c^2\, \rho\, \sigma^2} > 0 \quad \text{and} \\ \frac{\partial (E[r^*] - E[r_0])}{\partial \Delta q} &= \gamma\, \frac{b\, c\, \rho\, \sigma^2}{b + (1-\gamma)\, c^2\, \rho\, \sigma^2} > 0. \end{aligned}$$

Similarly, if households coordinate only on responsible investment, responsible consumption equals the optimal standard household's consumption. The equilibrium for a given responsible investment level i_R is defined by the following system of equations

$$\begin{aligned}
\frac{\partial \mathrm{E}U_S}{\partial q_S} &= \big(P - (a - b\, q_S)\big)\, \rho = 0, \\
\frac{\partial \mathrm{E}U_S}{\partial i_S} &= r_f - \lambda + i_S\, \rho\, \sigma^2 - \frac{P\, Q}{I} = 0, \\
I &= \gamma\, i_R + (1-\gamma)\, i_S, \\
Q &= q_S, \quad \text{and} \\
Q &= {}^{I}\!/_{c}.
\end{aligned}$$

The solution is retrieved analogous to the steps above with

$$\begin{aligned}
i_S^* &= \frac{c(a - c(r_f - \lambda)) - \gamma\, b\, i_R}{(1-\gamma)b + c^2\rho\sigma^2}, \\
q_S^* = Q^* &= \frac{(1-\gamma)(a - c(r_f - \lambda) + \gamma\, c\, \rho\, \sigma^2\, i_R}{(1-\gamma)b + c^2\rho\sigma^2}, \\
I^* &= c\, Q^*, \\
P^* &= \frac{a\, c^2\, \rho\, \sigma^2 + (1-\gamma) b\, c\, (r_f - \lambda) - \gamma\, b\, c\, \rho\, \sigma^2\, i_R}{(1-\gamma)b + c^2\rho\sigma^2}, \\
E[r^*] &= \frac{c\, \rho\, \sigma^2 (a + c\, \lambda) + (1-\gamma) b\, (r_f) - \gamma\, b\, \rho\, \sigma^2\, i_R}{(1-\gamma)b + c^2\rho\sigma^2}.
\end{aligned}$$

Using our clean benchmark, we can reformulate this to

$$\begin{aligned}
P^* &= P_0 + \gamma \frac{b\, c\, \rho\, \sigma^2}{(1-\gamma)b + c^2\, \rho\, \sigma^2} \left(c \frac{a - c\,(r_f - \lambda)}{b + c^2\, \rho\, \sigma^2} - i_R \right), \\
E[r^*] &= E[r_0] + \gamma \frac{b\, \rho\, \sigma^2}{(1-\gamma)b + c^2\, \rho\, \sigma^2} \left(c \frac{a - c\,(r_f - \lambda)}{b + c^2\, \rho\, \sigma^2} - i_R \right).
\end{aligned}$$

Substituting $i_R = i_S^*(0) - \Delta i$, where $i_S^*(0) = c\frac{a - c(r_f - \lambda)}{b + c^2\rho\sigma^2}$ is the amount a standard household would invest absent any responsible action as defined earlier, we get the prices as functions of the responsible deviation Δi as given in (29) and (30). Solely decreasing investment into brow firms, decreases dirty product prices and dirty investment returns compared to the clean benchmark,

$$\frac{\partial(P^* - P_0)}{\partial \Delta i} = -\gamma \, \frac{b\, c\, \rho\, \sigma^2}{(1-\gamma)b + \, c^2\, \rho\, \sigma^2} < 0 \quad \text{and}$$
$$\frac{\partial(E[r^*] - E[r_0])}{\partial \Delta i} = -\gamma \, \frac{b\, \rho\, \sigma^2}{(1-\gamma)b + \, c^2\, \rho\, \sigma^2} < 0. \qquad \blacksquare$$

Proof of Proposition 2: The proof is algebraically messy but straightforward. First, we solve the standard households' first-order conditions, market clearing conditions, and the production equation $c\,Q = I - I_F$ for q_S, i_S, Q, I and P. The equilibrium for a given responsible investment i_R and consumption level q_R is defined by equations (31) to (32) and $Q = (I - I_F)c$. Using this modified production function we can rewrite the first order condition with respect to i_S as

$$i_S^* = \frac{P/c + \lambda - r_f}{\rho\, \sigma^2} - \frac{I_F}{I^*} \frac{P/c}{\rho\, \sigma^2}.$$

In the aggregate, the capital market must clear,

$$I^* = \gamma\, i_R + (1-\gamma)\, \frac{\frac{P}{c}\, \frac{I^* - I_F}{I^*} + \lambda - r_f}{\rho\, \sigma^2}.$$

This resembles our benchmark condition except for the factor $(I^* - I_F)/I^*$. We can set $Q^* = \frac{I^* - I_F}{c}$ and insert the aggregate demand. The equilibrium quantity Q^* is now implicitly defined by the quadratic function

$$\begin{aligned} b\,(Q^*)^2 + (c\,Q^* + I_F)^2 \rho\, \sigma^2 = Q^*((1-\gamma)(a - c(r_f - \lambda)) + \gamma(b\, q_R + c\, \rho\, \sigma^2\, i_R)) \\ + I_F(i_R\, \gamma\, \rho\, \sigma^2 - (1-\gamma)(r_f - \lambda)). \end{aligned}$$

Note that in the limit $I_F \to 0$ the equilibrium quantity approaches our benchmark solution (36). We solve the equilibrium for given q_R and i_R to obtain the general equilibrium market responses for any responsible choice,

$$q_S^* = \frac{1}{2\,(1-\gamma)} \left(\frac{(1-\gamma)(a - c\,(r_f - \lambda)) - \gamma\, c^2 \rho\, \sigma^2\, (q_R - {}^{i_R}\!/_{c})}{b + c^2 \rho\, \sigma^2} - \gamma\, q_R + \frac{\sqrt{\Omega}}{b + c^2 \rho\, \sigma^2} - 2(1-\varphi)^{I_F}\!/_{c} \right)$$

$$i_S^* = \frac{c}{2\,(1-\gamma)} \left(\frac{(1-\gamma)(a - c\,(r_f - \lambda)) + \gamma\, b\, (q_R - {}^{i_R}\!/_{c})}{b + c^2 \rho\, \sigma^2} - \gamma\, i_R + \frac{\sqrt{\Omega}}{b + c^2 \rho\, \sigma^2} + 2\,\varphi\, {}^{I_F}\!/_{c} \right)$$

$$Q^* = \frac{1}{2} \left(\frac{(1-\gamma)(a - c\,(r_f - \lambda)) + \gamma\, (b\, q_R + c^2 \rho\, \sigma^2\, {}^{i_R}\!/_{c})}{b + c^2 \rho\, \sigma^2} + \frac{\sqrt{\Omega}}{b + c^2 \rho\, \sigma^2} - 2(1-\varphi)^{I_F}\!/_{c} \right) \quad (66)$$

$$I^* = \frac{c}{2} \left(\frac{(1-\gamma)\big(a - c\,(r_f - \lambda)\big) - \gamma\, (b\, q_R + c^2 \rho\, \sigma^2\, {}^{i_R}\!/_{c})}{b + c^2 \rho\, \sigma^2} + \frac{\sqrt{\Omega}}{b + c^2 \rho\, \sigma^2} + 2\,\varphi\, I_F \right) \quad (67)$$

$$P^* = \frac{1}{2} \left(\frac{\big(c^2 \rho\, \sigma^2\, a + b\, c\, (r_f - \lambda)\big) - \frac{\gamma}{1-\gamma}\, b\, c^2\, \rho\, \sigma^2\, (q_R - {}^{i_R}\!/_{c})}{b + c^2 \rho\, \sigma^2} \right)$$

$$+ \frac{b}{2\,(1-\gamma)} \left(((1-\gamma)^a\!/_b - \gamma\, b\, q_R) - \frac{\sqrt{\Omega}}{b + c^2 \rho\, \sigma^2} + 2\,(1-\varphi)^{I_F}\!/_{c} \right) \quad \text{where} \quad (68)$$

$$\Omega = \frac{4 I_F}{c} \Big((1-\gamma) a + \gamma b q_R + \frac{b I_F}{c} \Big) (b + c^2 \rho\, \sigma^2) + \left((1-\gamma)(a - (r_f - \lambda)) + \gamma\, b q_R + 2\, b\, \frac{I_F}{c} + c^2 \rho\, \sigma^2 \frac{i_R}{c} \right)^2$$

is an auxiliary variable. Note that the first term in each bracket resembles the benchmark equilibrium values without fixed costs.

We first calculate the marginal rate of transformation for exiting one unit of investment in units of boycott as (here we make use of the fact, that the externality is a linear function of investment I^*, where the fixed part I_0 does not affect the marginal effect of the responsible choice).

$$\text{MRT}_{i_R, q_R} = -\frac{\frac{\partial I^*}{\partial i_R}}{\frac{\partial I^*}{\partial q_R}} = -\frac{c\, \rho\, \sigma^2}{b} \frac{(1-\gamma)(a + c(r_f - \lambda) + \gamma\, (b\, q_R - c^2\, \rho\, \sigma^2 {}^{i_R}\!/_{c}) - \sqrt{\Omega}}{2\, c((I_F - \gamma i_R) \rho\, \sigma^2 + (1-\gamma)(r_f - \lambda))} \quad (69)$$

At the extreme, if responsible households fully exit and boycott the MRT becomes

$$\text{MRT}_{i_R \to 0, q_R \to 0} = -\frac{c\, \rho\, \sigma^2}{b} \frac{(1-\gamma)(a + c(r_f - \lambda)) - \sqrt{\Omega_0}}{2\, c(I_F \rho\, \sigma^2 + (1-\gamma)(r_f - \lambda))} \quad \text{with} \quad (70)$$

$$\Omega_0 = \frac{4 I_F}{c} \left((1-\gamma) a + \frac{b I_F}{c} \right) (b + c^2\, \rho\, \sigma^2) + \left((1-\gamma)(a - (r_f - \lambda)) + 2\, b\, \frac{I_F}{c} \right)^2.$$

To prove that complete boycott $q_R = 0$ and exit $i_R = 0$ are always a part of the optimal strategy, we will now prove that $\text{MRT}_{i_R\to 0, q_R\to 0} = \text{MRS}_{i_R\to 0, q_R\to 0}$. In other words, we prove that also with fixed costs, the iso-impact lines touch the iso-utility curve at the unique point $i_R \to 0, q_R \to 0$ such that proportional reduction is optimal at this point.

To calculate the marginal rate of substitution consider the expected utility of responsible households given the general equilibrium responses as described above

$$\text{E}U_R = u\Big(aq_R - bq_R^2/2 - P^*(q_R, i_R)q_R - bq_R^2 - i_R(r_f - \lambda) + r_f\, w_0 + i_R P^*(q_R, i_R)\frac{Q^*(q_R, i_R)}{I^*(q_R, i_R)} - i_R^2\, \rho\, \sigma^2\Big)$$

For brevity we leave aside the asterisk for the equilibrium values for market responses in the following notion. Using the implicit function theorem we solve for the marginal rate of substitution,

$$\text{MRS}_{i_R, q_R} = -\frac{\frac{\partial \text{E}U_R}{\partial i_R}}{\frac{\partial \text{E}U_R}{\partial q_R}} = -\frac{2a - 2bq_R + \frac{2i_R Q P'(q_R)}{I} + \frac{2i_R P Q'(q_R)}{I} - \frac{2i_R P Q I'(q_R)}{I^2} - 2q_R P'(q_R) - 2P}{\frac{2i_R Q P'(i_R)}{I} - 2q_R P'(i_R) + \frac{2i_R P Q'(i_R)}{I} - \frac{2i_R P Q I'(i_R)}{I^2} - 2i_R \rho\, \sigma^2 + \frac{2PQ}{I} - 2r_f} \tag{71}$$

Setting $i_R = 0$ and $q_R = 0$ this simplifies to

$$\text{MRS}_{i_R\to 0, q_R\to 0} = -\frac{(a - P^*(0,0))}{\frac{P(0,0)^* \cdot Q^*(0,0)}{I^*(0,0)} - r_f}. \tag{72}$$

Inserting (66), (67) and (68) at the point $i_R = 0$ and $q_R = 0$ we obtain

$$\text{MRS}_{i_R\to 0, q_R\to 0} = -\frac{c\, \rho\, \sigma^2}{b} \frac{(1-\gamma)(a + c(r_f - \lambda)) - \sqrt{\Omega_0}}{2\, c(I_F \rho\, \sigma^2 + (1-\gamma)(r_f - \lambda))} \tag{73}$$

which is identical to (70). Hence, the efficient combination of q_R and i_R is always a curve through the origin (if it is defined there). ■

B Heterogeneity

There are a few more special cases. If $b_R = b_S$, then the first fraction becomes $1/(1+\gamma)$. If $\rho_R = \rho_S$, then the inner bracket becomes $1+\gamma$. Now we discuss the three sources of heterogeneity in sequence, first $\rho_R \neq \rho_S$, then $a_R \neq a_S$, and finally $b_R \neq b_S$.

Heterogeneous Risk Aversion. We first discuss the effect of different degrees of risk aversion. Responsible households may have fewer opportunities to diversify and, therefore, may be more risk averse than standard households. We focus on the case $\rho_R > \rho_S$. Equation (11) turns into

$$q_R^* = \frac{1}{c} \, \frac{(1-\gamma)\,\frac{\rho_R}{\rho_S} + 2\,\gamma}{1+\gamma} \, i_R^*. \tag{74}$$

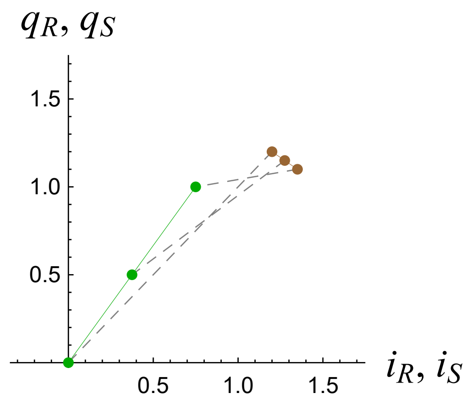
The intuition is as follows. If the risk aversion of responsible households is higher than that of standard households, reducing investment is relatively costly for responsible households and will be nearly completely offset by standard households. However, in equilibrium, responsible households will not invest much anyway due to their high-risk aversion. Hence, it is efficient to reduce investment only a little, but also from a low starting level. In the end, this leads to the proportionality result. Both investment and consumption are reduced in proportion.

Figure 10 illustrates the effects. The individually rational choice of responsible households would have $q_R = 1$ and $i_R = 0.75$. Standard households have a lower risk aversion. Therefore, they invest considerably more but consume about the same. The aggregate output is

$$I = c\,\frac{a - c\,(r_f - \lambda)}{b + c^2\,\rho_S\,\sigma^2}\,\frac{b\left(1-\gamma+2\,\frac{\rho_S}{\rho_R}\,\gamma\right) + (1+\gamma)\left(1-\gamma+\frac{\rho_S}{\rho_R}\,\gamma\right)c^2\,\rho_S\,\sigma^2}{b\left(1-\gamma+2\,\frac{\rho_S}{\rho_R}\,\gamma\right) + (1+\gamma)\,c^2\,\rho_S\,\sigma^2} = 1.05. \tag{75}$$

The product price is $P = 1.4$, and the expected return $r = P/c + \lambda$ is the same because $c = 1$ and $\lambda = 0$ in the example. Now, if responsible households reduce the externality efficiently, they follow (74) and reduce investment and consumption in proportion. Because

Figure 10: Expected Utility of Responsible Households, $\rho_R > \rho_S$



Parameters are $\rho_S = 1/3$, $\rho_R = 2/3$, and $\gamma = 50\%$, everything else as in Figure 2.

they initially had a lower share of investment, their reduction in investment is less palpable. Consequently, the price P increases and also the expected investment return r increases. Standard households react by investing more and consuming less, the brown point moves.

At the extreme point in the figure, $i_R = q_R = 0$. Aggregate output has dropped to

$$I = c\,\frac{a - c\,(r_f - \lambda)}{b + c^2\,\rho_S\,\sigma^2}\,(1 - \gamma) = 0.6. \tag{76}$$

The product price is at $= 1.45$. The externality $x\,I$ is reduced by less than half because of the reaction of standard households. When comparing (75) with (76), we see that the impact of responsible households on the aggregate externality is smaller (larger) than their share γ if $\rho_R > \rho_S$ ($\rho_R < \rho_S$). In summary, compared to Figure 3, the green line is steeper, but it still goes through the origin. Responsible households should still reduce investment and consumption proportionally.

Heterogeneous Product Substitutability. The substitutability parameter b may also differ between the two groups of investors. For example, responsible investors may find it easier to switch between producers such that $b_R > b_S$, or vice versa. Proposition 1 refers exclusively to the substitutability of standard households, so that the marginal rate of technical substitution becomes

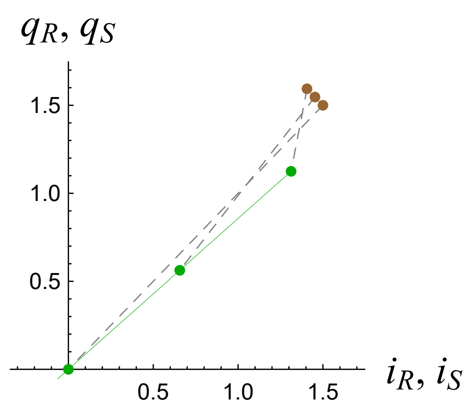
$$\frac{\rho\,\sigma^2}{b_S}\frac{1}{c}.$$

The impact of consumption reduction Δq disappears if *standard* households find it very easy to switch to another product. Proposition 1 also changes. Simplifying (11), it is still optimal for responsible households to reduce investment and consumption in proportion. However, the relation is now as follows

$$q_R^* = \frac{1}{c}\,\frac{1+\gamma}{(1-\gamma)\,\frac{b_R}{b_S} + 2\,\gamma}\,i_R^*. \tag{77}$$

In Figure 11, we have $b_S = 1/3$, and $b_R = 0.5$. The rational choice for each household

Figure 11: Expected Utility of Responsible Households, $b_R > b_S$



Parameters are $b_S = 1/3$, $b_R = 1/2 > b_S$, and $\gamma = 50\%$, everything else as in Figure 2.

is $q_R^* = 1.125$ and $i_R^* = 1.3125$. Standard households invest about the same and consume considerably more. The aggregate investment is at $I^* = 1.36$. Now as responsible households want to lower aggregate investment, they reduce consumption and investment in proportion, which leads to an increase in the price P and the expected return $r = P/c + \lambda$. Hence, standard households react by consuming less and investing more.

At the origin, $q_R^* = 0$ and $i_R^* = 0$, and the aggregate investment is $I^* = 0.75$. Although

50% of households are responsible, and they reduce consumption and investment to zero, the aggregate externality decreases by less than 50% because of the reaction of standard households.

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