Company-level GHG emissions and an institutional investor's active ownership objective

Long-term shareholder, socially responsible investor, common owner or stakeholder-oriented shareholder?*

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21 November 2022

Abstract

Academics and regulators have given significant attention to the impact of institutional investors on the companies in which they invest. Some are concerned that the institutional investors act as common owners. But in their active ownership policies institutional investors often say they are long-term shareholders, socially responsible investors, or stakeholder oriented. The evidence from the respective academic literatures seems to support both common ownership and the institutional investors' claims. We suggest this could arise because the natural experiments in the respective literatures do not analyze situations or outcomes that differentiate between the various active ownership objectives listed above. We demonstrate one example by examining the nascent literature on the association between firm-level greenhouse gas emissions and institutional investor influence. Subject to assumptions about the significance of the damage from climate change, we find the negative association between GHG emissions and institutional ownership is consistent with many active ownership objectives. We then extend our models to consider firms that can mitigate or adapt to the damage from GHG emissions and find separating conditions for the various active ownership objectives under particular industry conditions.

Keywords: corporate governance, climate change, common ownership, socially responsible investment, corporate social responsibility, stakeholder theory

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*We thank participants at the 29th Global Finance Conference, 12th Financial Markets and Corporate Governance Conference and 29th CEPAR Colloquium for helpful comments and suggestions, with particular thanks to discussants Qi Zeng and Carlos Alves. We also gratefully acknowledge financial support for Robert Annabel by Sasakawa Young Leaders Fellowship Fund, the Australian Government Research Training Program and State Super throughout the development of the paper.

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1 Introduction

Institutional ownership has reached significant levels globally. This has led some to suggest that institutional investors may play a significant role in addressing greenhouse gas ('GHG') emissions and anthropogenic climate change (e.g., Andersson, Bolton, and Samama, 2016; OECD, 2017; Bank of England, 2020; United Nations Climate Change Conference, 2021). Indeed, some institutional investors have publicly committed to address GHG emissions through active ownership (e.g., BlackRock's Global Executive Committee, 2021) and many institutional investors have active ownership policies outlining their approach to environmental, social and governance ('ESG') issues. These active ownership policies typically vary by institutional investor, but often embedded within these policies are aspects of familiar and perhaps well-intentioned corporate objectives: long-term shareholder value maximization (e.g., CalSTRS, 2021), socially responsible investment (e.g., ABP, 2020), and stakeholder theory (e.g., BlackRock, 2022).

High levels of institutional ownership, however, have also led to concerns about the possibility of institutional investors having less well-intentioned corporate objectives: common ownership.[1] Concerns about common ownership have recently motivated regulatory inquiries in both the US and Australia (e.g., FTC, 2018; Australian Federal Government, 2021). Common ownership has also had a resurgence in the academic literature. Recent theoretical models have generally confirmed the results of earlier models; common ownership is likely to lead to anti-competitive behaviour (e.g., Rotemberg, 1984; O'brien and Salop, 1999; Azar, 2017; Azar and Vives, 2021),[2] and greater internalization of spillovers/externalities,[3] such as pollution (e.g., Gordon, 1990; Hansen and Lott, 1996; Harford, 1997) and spillovers from innovation (e.g., Anton, Ederer, Gine, and Schmalz, 2018; López and Vives, 2019). But perhaps truly new to the common ownership literature in this resurgence is the increased availability of ownership data for quantitative empirics. The early quantitative empirical evidence investigating these predictions tended to focus on pricing (e.g., Azar, Schmalz, and Tecu, 2018; Azar, Raina, and Schmalz, 2019; Dennis, Gerardi, and Schenone, 2020). This pricing literature, however, has suffered from

[1] That is, as owners of multiple companies, within the same industry but also across industries, who make decisions with a portfolio-level decision frame with the objective of maximizing portfolio-level profits.

[2] The anticompetitive result in (Azar and Vives, 2021) is conditional on the elasticity of substitution between products in an economy being large in relation to the elasticity of labor supply. In Azar and Vives (2019), the estimates for these elasticities are sourced from Chetty, Guren, Manoli, and Weber (2011) and Hobijn and Nechio (2019), and found to be such that common ownership has anticompetitive effects. Intuitively, this seems fine; it seems much easier to change products in response to a changes in prices (so there is a large elasticity of substitution) than to change labor supply in response to changes in wages (a low elasticity of supply).

[3] We use the terms "externality" and "spillover" interchangeably throughout the paper. Unfortunately these terms have different meanings in the literatures with which we are trying to converse. The meaning we intend when using the words "externality" or "spillover" are those effects other than pricing effects, i.e. non-pecuniary, similar to how the terms are used in the corporate social responsibility and environmental economics literatures. Examples include pollution, and research and development spillovers.

endogeneity concerns, concerns about the validity of its' measures of common ownership, and conflicting results (e.g., Backus, Conlon, and Sinkinson, 2019; Gilje, Gormley, and Levit, 2020; Azar, Schmalz, and Tecu, 2021).

Due to these concerns, it has been suggested that researchers look beyond pricing as a dependent variable (Backus et al., 2019). Indeed, some have, looking towards externalities for evidence. But much of this evidence runs into a different issue; despite investigating common ownership, the evidence could be interpreted as consistent with those well-intentioned corporate objectives embedded in institutional investors' active ownership policies listed above. This is because these objectives also suggest that firms either consider the impact of externalities or the firm's impact on others, which generates correlations in the same direction. For example, the empirical evidence on increased voluntary disclosure (Park, Sani, Shroff, and White, 2019), higher levels of supply chain collaboration (Freeman, 2019) and increased innovation (Anton et al., 2018) focus on common ownership, but may be considered somewhat consistent with institutional investors having other active ownership objectives, such as long-term shareholder value, socially responsible (if pivotal) investor objectives[4] (e.g., Hart and Zingales, 2017; Morgan and Tumlinson, 2019), or stakeholder value (e.g., Freeman, 1984; Freeman, Phillips, and Sisodia, 2020). Indeed, recent evidence in the corporate social responsibility literature, akin to socially responsible investment, uses environmental and social performance to argue institutional investors encourage corporate social responsibility (e.g., Dyck, Lins, Roth, and Wagner, 2019; Chen, Dong, and Lin, 2020), which could also be interpreted as consistent with common ownership (e.g., Hansen and Lott, 1996; Harford, 1997; Dai and Qiu, 2020).

We contribute to solving this active ownership identification problem in the context of GHG emissions. To dos so, we combine elements from the literature on corporate objectives and environmental industrial organization. First, using the negative association between GHG emissions and institutional investor influence from the nascent quantitative empirical literature concerning such a topic, we demonstrate the active ownership identification problem in a model similar to that used in the hypothesis development of Azar, Duro, Kadach, and Ormazabal (2021).[5] That is, we show that the negative correlation between institutional investor influence and firm-level GHG emissions could be interpreted as consistent with every active ownership objective. We do, however, also show that the stakeholder-oriented shareholder is the only active owner type who may, but does not necessarily, increase quantities and emissions relative to the short-term profit maximizer. Thus, the stakeholder-oriented shareholder can be separated from other active ownership types when a positive correlation between institutional investor influence and firm-level quantities and emissions is observed.

[4]For a thorough discussion of the difference between being prosocial if pivotal and socially responsible, see Hart and Zingales (2017). To summarize, the argument revolves around commission and omission.

[5]Specifically, we model GHG emissions as an inseparable negative externality similar to Hansen and Lott (1996) and Harford (1997)

Second, we introduce industries in which firms can mitigate or adapt to the damage from GHG emissions. Mitigation reduces emissions and thus is like a public good, whilst adaptation reduces damage to the firm and thus is like a private good. We find that all active ownership types increase mitigation relative to the short-term profit maximizer, except the short-term common owner. Thus, the short-term common owner can be differentiated from the other active owners. This result is driven by the myopia of short-term common owner; they do not consider the future, so they do not invest in mitigation or adaptation beyond that required by regulation. We then consider the results of Akey and Appel (2019) and Naaraayanan, Sachdeva, and Sharma (2020), who both investigate the association between institutional investor influence and firm-level investments in mitigation for different types of institutional investors. Based on our model, we suggest that the results of Akey and Appel (2019) indicate hedge funds behave like short-term common owners, whilst the results of Naaraayanan et al. (2020) show only that the institutional investors associated with the Boardroom Accountability Project ('BAP') do not behave as short-term common owners, but not necessarily that they are long-term shareholders and/or stakeholder-oriented shareholders as the authors seem to claim.

We then derive two further industry conditions to separate the remaining active ownership objectives: long-term shareholders, SRIs, long-term common owners and stakeholder-oriented shareholders. The first set of industry conditions is when there is no exposure to damage from emissions for firms in an industry. In such cases, the long-term profit maximizer can be separated from the other active ownership objectives by no increase in mitigation. This result is driven by the private good nature of adaptation and public good nature of mitigation; the long-term shareholder only cares about the payoffs to the firm, so, if the long-term shareholder is not exposed to damage, then they do not mitigate beyond that required by regulation. If, in addition to the firm not being exposed to damage, the incentive to expand production is larger than the incentive to mitigate, the stakeholder-oriented shareholder can be differentiated by an increase in quantities and emissions whilst also increasing mitigation.

The second set of industry conditions is when consumers have high willingness to pay and revenue is a non-monotonic function of quantities.[6] When willingness to pay is high, the short-term profit maximizer chooses quantities above that which maximizes revenue. Thus, the effect on revenue of decreasing quantities (as is done by both the SRI and long-term common owner) could be positive or negative. We find that in such a circumstance that, if the common ownership incentives are sufficiently large, then SRIs increase revenue and long-term common owners decrease revenue.

[6]Willingness to pay is the maximum price at which a consumer is willing to buy a product. Non-monotone revenue arises naturally when i) the maximum willingness to pay is finite, known as a choke price, and ii) prices approach zero as quantities become large.

The rest of the paper proceeds as follows. In Section 2, we use models from the field of industrial organization and adopt different active ownership objectives to show that the results in nascent literature on GHG emissions and institutional investor influence could be consistent with institutional investors acting according to several active ownership objectives. In Section 3, we first extend the models in Section 2 to allow firms to mitigate and adapt to climate change, which creates some separation of active ownership objectives, then consider the industry conditions that allow further separation of active ownership objectives. By combining these results, a set of predictions to differentiate the active ownership types under various industry conditions and using various outcomes is generated. In Section 4 we conclude.

2 The active ownership identification problem in the context of GHG emissions

Recently, to the best of our knowledge, there have been five (working) papers published containing results for the quantitative association between GHG emissions and institutional investor[7] influence: Shive and Forster (2020), Azar et al. (2021), Akey and Appel (2019), Naaraayanan et al. (2020), Benlemlih, Arif, and Nadeem (2022). All papers find a negative association between institutional investor influence and GHG emissions.[8] In light of this information, the questions raised by this paper are; if we are seeking to identify what type of active owner institutional investors are acting as, what can we conclude with this information? Are institutional investors' long-term shareholders, socially responsible investors, or stakeholder-oriented as they claim? Or are they common owners? In this section, by modelling GHG emissions as an inseparable negative externality similar to the papers used in the hypothesis development of Azar et al. (2021),[9] we show, subject to some assumptions about the significance of damage from climate change, that the answer to these questions is: the information suggests they could be any of those and may only rule out institutional investors being short-term profit maximizers.

To show this, we proceed as follows. First, we construct a benchmark model where firms are short-term profit maximizers. We then construct alternative models in which institutional investors instruct firms to adopt other objective functions. Finally, we compare equilibrium firm-level emissions in the alternative models to the benchmark model. As expected, we find

[7]Of various types: mutual funds, the Big Three asset managers (BlackRock, State Street, Vanguard), hedge funds and those institutional investors associated with the Boardroom Accountability Project.

[8]Akey and Appel (2019) and Naaraayanan et al. (2020) also report results for the association between institutional investor influence and investments in abatement. We deal with this further below when we introduce a model with mitigation. We see abatement as akin to mitigation.

[9]Hansen and Lott (1996) and Harford (1997).

that equilibrium firm-level emissions are lower in every alternative model than in the benchmark model if damage from climate change is considered to be sufficiently large. Therefore, according to these models the observed negative association in the literature on GHG emissions and institutional investor influence could be a result of adopting any of the active ownership policies represented in Section 2.2 below, except short-term profit maximization.

2.1 Model set-up

We consider a partial equilibrium model[10] of an economy as follows. There are N goods; q, y, and $N-2$ other goods denoted r_n where $n = 1, 2 \ldots, N-2$. These goods are produced by N sectors; Sector Q, Sector Y, and a sector for each r_n denoted Sectors R_n. There is perfect competition in Sector Y which produces the numeraire good y. There is Cournot duopoly in homogeneous goods in Sectors Q and R_n with $I = 2$ firms in each industry, with each firm in Sector Q denoted $i = 1, 2$ and each firm in Sector R_n denoted $k_n = 1, 2$.

There is one factor of production, labor denoted L, and it is mobile across sectors. Sectors Q and R_n produce good q using r_n with the production technologies $Q = \frac{L_Q}{c}$ and $R_n = \frac{L_{R_n}}{c}$, respectively. Sector Y produces good y using L with the production technology $Y = L_Y$. Total labor is restricted to $L_Q + L_Y + \sum_n L_{R_n} = L$. Wages per unit of labor is represented by w.

Production of goods y and r_n do not result in emissions. But production of good q does result in emissions for each firm, e_i, where the units for emissions per unit of production are chosen so that $q_i = e_i$. These emissions add to the current stock of emissions in the atmosphere, E_0, so that total emissions in the atmosphere is $E = E_0 + e_1 + e_2$. Emissions result in damage to every firm in Sectors Q and R_n[11] at some future time point. The damage to each firm in Sectors Q and R_n is given by $\delta\gamma_f E$, where $0 < \delta \leq 1$ represents the time discount rate and $\gamma_f > 0$ represents the severity of damage to an individual firm. To address the damage, government has set a tax, $t > 0$, per unit of emissions.[12]

[10] Thus, the model does not account for wealth effects. For general equilibrium models of common ownership that do account for wealth effects, see Azar and Vives (2021) and Azar and Vives (2019), who account for wealth effects arising from labor income and interest income. Both find that higher common ownership leads to lower output under realistic parameterizations. Also relevant in this regard is Gans, Leigh, Schmalz, and Triggs (2019), who account for ownership-related income and show that asymmetric ownership leads to higher prices than if ownership were symmetric.

[11] For simplicity, we ignore damage to Sector Y.

[12] That is, we assume taxes are exogenous and do not model the tax choice for the government. In the model we have constructed, however, one could raise the concern that it is not necessarily the case that the government would choose taxes, $t > 0$, instead of subsidies, $t < 0$, because it is possible that the level of production in oligopolies is below the production level that maximizes welfare net of damage from emissions. In addition to suggesting that taxes are a realistic assumption in this circumstance, we address this concern by noting that, if taxes were endogenous and set optimally by a government in our model, then one requires the assumption that $a < 3\delta\gamma + c$ to ensure a tax, i.e. $t > 0$, would be set by the government. See Appendix A.4 for working.

Combining the information above, the (long-term) profits of firm i in Sector Q are therefore given by:

$$\tilde{\pi}_{Q,i} = (p_Q - c)q_i - te_i - \delta\gamma_f E = (p_Q - c - t)q_i - \delta\gamma_f E = \pi_{Q,i} - \delta\gamma_f E \quad (1)$$

since $q_i = e_i$, and where p_Q is the price in Sector Q and $\pi_{Q,i}$ represents firm profits without damage from emissions but inclusive of any taxes imposed by the government for producing emissions. Similarly, the (long-term) profits for firm k_n in Sector R_n are given by:

$$\tilde{\pi}_{R_n,k_n} = (p_{R_n} - c)r_{n,k_n} - \delta\gamma_f E = \pi_{R_n,k_n} - \delta\gamma_f E, \quad (2)$$

where p_{R_n} is the price in Sector R_n and π_{R_n,k_n} represents firm profits without damage from emissions but inclusive of any taxes imposed by the government for producing emissions.[13]

There are two groups, consumer-workers and institutional investors, who own the firms in the economy. The firms in Sector Q and Sector R_n are directly owned by both consumer-workers and institutional investors, the latter owning firms for the benefit of consumer-workers, whilst the firms in Sector Y are directly owned only by consumer-workers. There is a unit mass, $0 \leq j \leq 1$, of consumer-workers, each denoted j, who derive utility from consuming goods q, r_n and y, and disutility from the damage from emissions, given by $\gamma_{cw}E$. A representative consumer j's utility function is:[14]

$$U_j(Q_j, R_{n,j}, y_j) = aQ_j - \frac{Q_j^2}{2} + \sum_n \left(aR_{n,j} - \frac{R_{n,j}^2}{2} \right) + y_j - \delta\gamma_{cw}E. \quad (3)$$

Each consumer-worker has L_j units of labor from which they earn a labor income wLj. As the owners of the firms in Sector Y, consumer-workers receive zero profits. As owners of Sectors Q and R_n, consumer-workers collectively directly own c_Q and c_{R_n} percent of each of Sectors Q and Sector R_n, and are recipients of the remainder through institutional investors to whom they pay a management fee as a percentage of assets of α.[15] Therefore, they collectively receive from their direct ownership $c_Q\Pi_Q + \sum_n c_{R_n}\Pi_{R_n}$, where $\Pi_Q = \sum_i \tilde{\pi}_{Q,i}$ and $\Pi_{R_n} = \sum_{k_n} \tilde{\pi}_{R_n,k_n}$, and collectively receive $(1-\alpha)((1-c_Q)\Pi_Q + \sum_n(1-c_{R_n})\Pi_{R_n})$ through institutional investors. These collective costs and benefits, however, are assumed to be spread amongst infinitely many consumer-workers and therefore are approximately equal to zero for any individual consumer-worker. Thus, when making their consumption and labor decisions,

[13] See Appendix A.2 for working related to these equations.

[14] A quasi-linear quadratic utility function that is linear in the numeraire (money), y, and quadratic in all other goods, q and r_n. We have added a term that is linear in damage from emissions. Assuming utility is linear in the numeraire simplifies the analysis by removing wealth effects, the impact of which is discussed in footnote 10. For the impact of the remaining terms, see Section 4 discussing results and limitations.

[15] The distinction between direct and indirect ownership is made for reasons related to choosing the firm objective, on which we elaborate below.

consumer-workers budget constraint can be simplified to $wL_j \geq y_j + p_Q Q_j + \sum_n p_{R_n} R_{n,j}$, and, therefore, the inverse demand functions for Sectors Q and R_n are given by:[16,17]

$$p_Q = a - Q, \tag{4}$$

$$p_{R_n} = a - R_n, \tag{5}$$

where $Q = q_1 + q_2$ and $R_n = r_{n,1} + r_{n,2}$.

We assume there are two institutional investors, $m = 1, 2$, whose utility is only a function of good y[18] and is therefore given by:

$$U_m(Q_m, R_{n,m}, y_m) = y_m. \tag{6}$$

The institutional investors collectively manage $(1 - c_Q)\Pi_Q + \sum_n (1 - c_{R_n})\Pi_{R_n}$ of wealth and both charge a percentage fee of the assets they individually manage of α. We assume that each institutional investor individually manages a portfolio of investments in firms in Sector Q and Sector R_n industries such that the total assets under management ('AUM') of institutional investor m, denoted AUM_m, is given by:

$$AUM_m = (1 - c_Q) \sum_i w_{Q,i,m} \tilde{\pi}_{Q,i} + \sum_n (1 - c_{R_n}) \sum_{k_n} w_{R_n,k_n,m} \tilde{\pi}_{R_n,k_n}, \tag{7}$$

where $w_{Q,i,m}$ represents the ownership of institutional investor m of firm i in Sector Q which is then scaled by the proportion of direct ownership of Sector Q of consumer-workers so that institutional investor m's actual direct ownership is $(1 - c_Q)w_{Q,i,M}$. Note $w_{Q,i,m} + w_{Q,i,-m} = 1$ and $w_{R_n,k_n,m} + w_{R_n,k_n,-m} = 1$, because total ownership proportions sum to 1. For example, $(1 - c_Q)w_{Q,i,m} + (1 - c_Q)w_{Q,i,-m} + c_Q = 1$. Finally, we assume that institutional investor ownership within industries is represented by symmetric common ownership. That is $w_{Q,i,m} = w_{Q,-i,-m}$ and $w_{R_n,k_n,m} = w_{R_n,-k_n,-m}$. Therefore, the budget constraint of institutional investors is given by $\alpha AUM_m \geq y_m$.

Finally, we assume that the firm objective is determined by the institutional investor with the largest ownership share of the firm according to their active ownership objective and, for simplicity, active ownership objectives are the same across institutional investors. In our

[16] See Appendix A.3 for working related to the demand functions.

[17] We assume identical demand curves for all sectors, other than Sector Y, for simplicity. Nothing changes qualitatively if we relax this assumption.

[18] We believe such an assumption aligns most directly with maximising portfolio value, which can be seen by substituting the budget constraint of the institutional investors into the utility function. The idea that an institutional investor does not necessarily maximise portfolio value due to agency issues could be an interesting area for further research, but is beyond the scope of our paper focusing on a set of well-known objective functions (see Section 2.2 that follows).

model, consumer-workers' collective ownership of a firm in a sector is spread amongst infinitely many consumer-workers, so we assume they display rational apathy with respect to corporate governance matters such as determining the firm objective. As a result, only the two institutional investors are involved in the determination of the firm objective. Since we have symmetric common ownership with two owners in our model, one of the institutional investors is pivotal in a majority voting game; that is, $w_{Q,i,m} = w_{Q,-i,-m} > 0.5$ and $w_{R_n,k_n,m} = w_{R_n,-k_n,-m} > 0.5$. Thus, we assume that the pivotal institutional investor selects the firm objective according with their active ownership objective. Furthermore, for simplicity, we assume that institutional investors have identical active ownership objectives. Thus, firm objectives are also identical.

2.2 Active ownership objectives

The set of active ownership objective functions for institutional investors is outlined below. We focus on Sector Q since it is the sector producing emissions and will thus be the sector on which we focus for the remainder of the paper. Each function is presented such that it builds on short-term and long-term profit maximization by additionally considering some other stakeholder payoff. First, there is short-term profit maximization, in which only short-term profit is considered:

$$\phi_{STP} = \pi_{Q,i} = (p_Q - c - t)q_i. \tag{8}$$

Second, the institutional investor with a long-term profit maximization objective accounts for the damage to the firm from emissions since this damage arrives in the future:

$$\phi_{LTP} = \tilde{\pi}_{Q,i} = \pi_{Q,i} - \delta\gamma_f E = \phi_{STP} - \delta\gamma_f E, \tag{9}$$

where $E = E_0 + e_1 + e_2$, δ is the time discount factor, and γ_f is a parameter reflecting the severity of damage to a firm.

Common owners consider the interests of other firms in their investment portfolios, see Schmalz (2018) for a survey. We consider two types of common ownership; one where the GHG externality is considered (and therefore directly reflects the institutional investors' utility function), which we label long-term common ownership, and one where the GHG externality is not considered, which we label short-term common ownership. First is short-term common ownership ('STCO'), where the objective function can be written as:

$$\phi_{STCO} = (1 - c_Q) \sum_i w_{Q,i,m} \pi_{Q,i} + \sum_n (1 - c_{R_n}) \sum_{k_n} w_{R_n,k_n,m} \pi_{R_n,k_n} \tag{10}$$

$$\propto \pi_{Q,i} + \lambda_{INTRA,Q} \pi_{Q,-i} + \sum_n \lambda_{INTER,R_n} (\pi_{R_n,k_n} + \lambda_{INTRA,R_n} \pi_{R_n,-k_n}), \tag{11}$$

where $\lambda_{INTRA,Q} = \frac{w_{Q,-i,m}}{w_{Q,i,m}}$, $\lambda_{INTRA,R_n} = \frac{w_{R_n,-k_n,m}}{w_{R_n,k_n,m}}$, and $\lambda_{INTER,R_n} = \frac{(1-c_R n) w_{R_n,k_n,m}}{(1-c_Q) w_{Q,i,m}} > 0$.

For simplicity, we assume $\lambda_{INTRA,Q} = \lambda_{INTRA,R_n} = \lambda_{INTRA}$ and for reasons relevant to explanations later in the paper note that $0 < \lambda_{INTRA} < 1$.[19] Here, λ_{INTRA} reflects the intra-industry (anti-competitive) incentive of common ownership in firm decisions in Sectors Q and R_n, whilst λ_{INTER,R_n}, roughly speaking, reflects the inter-industry incentives of common ownership arising from actions in Sector Q that affect Sectors R_n. Note that in our model the only mechanism through which the actions of Sector Q affect any Sector R_n is through emissions, E, which is not in the short-term common owner's objective. Therefore, λ_{INTER,R_n} will play no role for the short-term common owner. Finally, note that since the objective, Equation 10, is equal to Equation 11 divided by the constant $w_{Q,i,m}$, maximising the objective is equivalent to maximising Equation 11 which we rewrite as:

$$\tilde{\phi}_{STCO} = \pi_{Q,i} + \lambda_{INTRA,Q} \pi_{Q,-i} + \sum_n \lambda_{INTER,R_n} (\pi_{R_n,k_n} + \lambda_{INTRA,R_n} \pi_{R_n,-k_n}). \tag{12}$$

Second is long-term common ownership ('LTCO'), where the objective function can be written as:

$$\phi_{LTCO} = (1 - c_Q) \sum_i w_{Q,i,m} \tilde{\pi}_{Q,i} + \sum_n (1 - c_{R_n}) \sum_{k_n} w_{R_n,k_n,m} \tilde{\pi}_{R_n,k_n} \tag{13}$$

$$\begin{aligned}
&\propto \tilde{\pi}_{Q,i} + \lambda_{INTRA,Q} \tilde{\pi}_{Q,-i} + \sum_n \lambda_{INTER,R_n} (\tilde{\pi}_{R_n,k_n} + \lambda_{INTRA,R_n} \tilde{\pi}_{R_n,-k_n}) \\
&= \pi_{Q,i} + \lambda_{INTRA,Q} \pi_{Q,-i} + \sum_n \lambda_{INTER,R_n} (\pi_{R_n,k_n} + \lambda_{INTRA,R_n} \pi_{R_n,-k_n}) \\
&\quad - \delta \gamma_f E (1 + \lambda_{INTRA,Q} + \sum_n \lambda_{INTER,R_n} (1 + \lambda_{INTRA,R_n}) \\
&= \tilde{\phi}_{STCO} - \delta \gamma_f E (1 + \lambda_{INTRA})(1 + \sum_n \lambda_{INTER,R_n}) \\
&= \tilde{\phi}_{STCO} - \delta \gamma_f E (1 + \lambda_{INTRA})(1 + \lambda_{INTER}) \\
&= \tilde{\phi}_{STCO} - \delta \gamma_{CO} E
\end{aligned} \tag{14}$$

[19]The bounds on these parameters are derived from the assumed ownership structure, which is symmetric common ownership. As discussed in Backus et al. (2019), there may be no upper bound on the intra-industry common ownership incentive. Our results, including those separating the long-term common owner and SRI, are not changed by removing the upper bound on the intra-industry common ownership incentive.

since $\lambda_{INTRA,Q} = \lambda_{INTRA,R_n} = \lambda_{INTRA}$, and where $\lambda_{INTER} = \sum_n \lambda_{INTER,R_n} > 0$ and $\gamma_{CO} = \gamma_f(1 + \lambda_{INTRA})(1 + \lambda_{INTER})$.

Here, λ_{INTER} reflects the sum total inter-industry incentives of common ownership arising the emissions-related actions in Sector Q that affect Sectors R_n. Note that in contrast to the short-term common owner, λ_{INTER} will play a role since the long-term common owner considers damage from GHGs to firms in their portfolio. Finally, note that for similar reasons to those given for the short-term common owner, maximising the objective, Equation 13, is equivalent to maximising:

$$\tilde{\phi}_{LTCO} = \tilde{\phi}_{STCO} - \delta\gamma_{CO}E. \tag{15}$$

We now consider social responsibility and stakeholder theory. Similar to Hart and Zingales (2017),[20] the SRI maximizes long-term profits less the damage to others:

$$\phi_{SRI} = \tilde{\pi}_{Q,i} - \beta E((NI - 1)\delta\gamma_f + \delta\gamma_{cw}) = \phi_{STP} - \delta\gamma_{SRI}E, \tag{16}$$

where $\gamma_{SRI} = \gamma_f + \beta((NI - 1)\gamma_f + \gamma_{cw})$, γ_f represents the long-term damage to the firm itself, $0 < \beta \leq 1$ reflects the discount to damage to others from GHGs ('SRI discount factor'), γ_{cw} is the damage to consumer-workers and $(NI - 1)\gamma_f$ is the damage to the other firms in Sector Q and Sectors R_n.

Finally, in addition to the firm's long-term profits and the damage to the 'community' (Freeman et al., 2020),[21] the stakeholder-oriented shareholder considers the consumption benefit to consumer-workers:[22]

$$\begin{aligned}\phi_S &= \tilde{\pi}_{Q,i} + \theta(U_{cw}(Q, R_n, y) - E((NI - 1)\delta\gamma_f + \delta\gamma_{cw}))\\ &= \phi_{STP} + \theta U_{cw}(Q, R_n, y) - \delta\gamma_S E,\end{aligned} \tag{17}$$

where $\gamma_S = \gamma_f + \theta((NI - 1)\gamma_f + \gamma_{cw})$, U_{cw} is the utility of consumer-workers from consumption

[20] Mathematically we directly follow Hart and Zingales (2017) in including profits and damage in the objective function. However, conceptually it is not clear that we follow them. There is an alternative view of social responsibility often expressed in the SRI and CSR literature that equates SRI and CSR to stakeholder theory in the sense that other's interests are considered (e.g. Broccardo, Hart, and Zingales, 2020; Dai and Qiu, 2020). But CSR is not stakeholder theory Freeman and Dmytriyev (2017). CSR and SRI (and ESG for that matter) are concerned with the pursuit of broad social issues (e.g. Renneboog, Ter Horst, and Zhang, 2008; Freeman and Dmytriyev, 2017; Gillan, Koch, and Starks, 2021). We follow this latter definition of SRI, CSR and ESG and consider those objectives where stakeholder interests are considered in total, so including but also beyond how the stakeholders may be are affected by the social issues that are the focus of SRIs, as being a more accurate mathematical representation of stakeholder theory.

[21] We assume the 'community' is represented by Sector Y, Sectors R_n, the other firm in Sector Q and consumer-workers, so the damage term for the stakeholder value maximizer consists of precisely the same damage terms as considered by the SRI.

[22] The closest to this in the economics literature Magill, Quinzii, and Rochet (2015)

only (so excluding their share of the damage from the GHG emissions externality) and $0 < \theta \leq 1$ reflects the discount to stakeholder interests ('stakeholder discount factor').[23]

2.3 The benchmark model

In the benchmark model, we assume firms in Sector Q aim to maximize short-term profits by choosing quantities only. That is, each firm simultaneously chooses quantities, q_i, to maximize their objective:

$$\phi_{STP} = \pi_{Q,i} = (p_Q - c - t)q_i = (a - q_i - q_{-i} - c - t)q_i. \tag{8}$$

Emissions, e_i, is then an outcome that is a by-product of the choice of q_i only. This is because the level of emissions is $q_i = e_i$ with appropriate units for emissions (See Section 2.1).

Given the model set-up, the Cournot-Nash equilibrium firm-level quantity for each firm in the benchmark model, $q^*_{i,BM}$, is given by:[24]

$$q^*_{i,BM} = \frac{a - c - t}{3}, \tag{18}$$

which is the conventional Cournot-Nash equilibrium quantity in duopoly adjusted for the tax for emissions associated with production. The level of emissions in the benchmark model, $e^*_{i,BM}$, is also given by:

$$e^*_{i,BM} = \frac{a - c - t}{3} \tag{19}$$

since in the model units of emissions are chosen such that $q_i = e_i$.

2.4 Comparison of the results from the alternative models to the results of the benchmark model

In this section, we present results comparing the benchmark model and the set of alternative models. Each model in the set of alternative models corresponds to institutional investors having one of the active ownership objectives in Section 2.2, and therefore firms having the same firm objectives, other than short-term profit maximization. We split our results in two. In the first set of results, we present comparisons of all active ownership objectives, except

[23] We acknowledge that stakeholder value maximization may go beyond consumption benefits and the damage from emissions.

[24] See Appendix B.1 for working.

the alternative model with stakeholder-oriented shareholders, to the benchmark model. In the second set, we focus on results related to the stakeholder-oriented shareholder. Further note that in our results we do not assume a common time discount factor, δ, across those active ownership objectives in which δ appears and likewise for the intra-industry incentive, λ_{INTRA} unless otherwise specified.

2.4.1 Active ownership objectives other than stakeholder

The results for quantities and emissions (since they are equal) for all active ownership objectives except stakeholder-oriented shareholders are given by:[25]

$$q^*_{i,\phi} = e^*_{i,\phi} = \frac{a - c - t - \delta\gamma_\phi}{3 + \xi_\phi}, \tag{20}$$

where ϕ signifies the active ownership objective, and $\delta\gamma_\phi$ and ξ_ϕ differ by active ownership objective. Specifically, $\delta\gamma_\phi = \delta\gamma_f$ and $\xi_\phi = 0$ for the long-term profit maximizer, $\delta\gamma_\phi = 0$ and $\xi_\phi = \lambda_{INTRA}$ for the short-term common owner, $\delta\gamma_\phi = \delta\gamma_{CO}$ and $\xi_\phi = \lambda_{INTRA}$ for the long-term common owner, and $\delta\gamma_\phi = \delta\gamma_{SRI}$ and $\xi_\phi = 0$ for the SRI.

Since for the short-term profit maximizer $\delta\gamma_\phi = 0$ and $\xi_\phi = 0$, all the above active ownership types reduce quantities and emissions relative to the short-term profit maximizer; the numerator decreases or the denominator increases.

Proposition 1. *Quantities and emissions relative to the benchmark model (that is, the short-term profit maximizer) are:*

i. Lower for the long-term profit maximizer for all time discount factors $0 < \delta \leq 1$*;*

ii. Lower for the short-term common owner for all intra-industry incentives $0 < \lambda_{INTRA} < 1$*;*

iii. Lower for the long-term common owner for all time discount factors $0 < \delta \leq 1$*, intra-industry incentives* $0 < \lambda_{INTRA} < 1$ *and inter-industry incentives* $\lambda_{INTER} > 0$*; and*

iv. Lower for the SRI for all time discount factors $0 < \delta \leq 1$ *and SRI discount factors* $0 < \beta \leq 1$*.*

The incentives driving these results can be sorted into three categories: the long-term incentive from damage to the firm, the incentive arising from damage to other agents in the model, and the intra-industry common ownership incentive. The long-term incentive relates to future damage to the firm. This drives the reduction in emissions relative to the short-term profit maximizer for all except the short-term common owner. There is then the incentive due to damage to other agents in the model, which influences the long-term common owner and SRI; the long-term common considers other firms in their portfolio and for the SRI considers the

[25] See Appendices B.2 to B.5 for working.

damage to all agents. Finally, both the short-term and long-term common owners are driven by the intra-industry common ownership incentive. In the case of the short-term common owner, the intra-industry common ownership incentive is the only incentive driving the result.

2.4.2 Stakeholder-oriented shareholders

Quantities and emissions for the stakeholder-oriented shareholder are given by:[26]

$$q_{i,S}^* = e_{i,S}^* = \frac{a - c - t - \delta\gamma_S}{3 - 2\theta}. \tag{21}$$

From the above equation it can be seen that quantities and emissions relative to the short-term profit maximizer are ambiguous; the numerator decreases, but the denominator decreases too.

Proposition 2. *Quantities and emissions relative to the benchmark model (that is, the short-term profit maximizer) are:*

i. Lower for the stakeholder-oriented shareholder for all $0 < \theta \leq 1$ *when* $Q_{BM}^* - \delta(\gamma - \gamma_f) < 0$*; and*

ii. Lower [higher] for the stakeholder-oriented shareholder if and only if the stakeholder discount factor $\theta < \theta^*(\delta)$ *[*$\theta > \theta^*(\delta)$*] when* $Q_{BM}^* - \delta(\gamma - \gamma_f) > 0$.

where $\theta^*(\delta) = \frac{\delta\gamma_f}{Q_{BM}^* - \delta(\gamma - \gamma_f)}$ *and* $Q_{BM}^* = 2q_{BM}^*$

Unlike the results for other active owners in in Section 2.4.1, the stakeholder-oriented shareholder does not necessarily reduce quantities and emissions. The different result is driven by stakeholder-oriented shareholders having an incentive to expand production as they consider the consumption benefit for consumer-workers. In contrast, all other active ownership objectives only include incentives to reduce production. Since the stakeholder-oriented shareholder's incentive to expand production is moderated by θ, and their incentives to reduce production are moderated by δ and θ, the net incentive depends on δ and θ.

Separating the incentives into those terms associated with θ and those associated with δ only, $\theta^*(\delta)$ essentially becomes the ratio of marginal damage to the firm from expanding production to the net marginal benefit of production (so consumption minus damage) to stakeholders other than the firm. That is:

$$\theta^*(\delta) = \frac{\delta\gamma_f}{Q_{BM}^* - \delta(\gamma - \gamma_f)}. \tag{22}$$

From this equation it can be seen that if the consumption benefit is less than the damage to

[26] See Appendix B.6 for working.

stakeholders other than the firm, as represented by $Q^*_{BM} - \delta(\gamma - \gamma_f) < 0$ and corresponding to Proposition 2.i., $\theta^*(\delta)$ is negative. Thus, $\theta > \theta^*(\delta)$ holds for any $0 < \theta \leq 1$.

But if the consumption benefit is greater than the damage to stakeholders other than the firm, then the damage to the firm must be traded off against the net benefit to stakeholders other than the firm in order to determine whether to reduce quantities and emissions. Despite this ambiguity, conditions under which any stakeholder-oriented shareholder will reduce quantities when $Q^*_{BM} - \delta(\gamma - \gamma_f) > 0$ can be derived.[27] The derivation follows from finding industry characteristics such that $\theta^*(\delta) > 1$, which means $\theta < \theta^*(\delta)$ holds for any $0 < \theta \leq 1$. The exercise effectively ensures that the damage from emissions to all stakeholders is larger than the consumption benefit as assessed by any stakeholder-oriented shareholder (so with any θ).

Thus, there is a set of industry characterisitcs for which any stakeholder-oriented shareholder will reduce quantities and emissions relative to the short-term profit maximizer. Combining this result with that of Proposition 1 leads to the following corollary relating all active ownership objectives to the benchmark model, where δ_S is the time discount factor corresponding to the stakeholder-oriented shareholder.

Corollary 1 (The active ownership identification problem in the context of GHG emissions). *If $Q^*_{BM} \leq \delta_S\gamma$, quantities and emissions relative to the benchmark model are lower for all active ownership objectives for all time discount factors $0 < \delta \leq 1$, intra-industry incentives $0 < \lambda_{INTRA} < 1$, inter-industry incentives $\lambda_{INTER} > 0$, SRI discount factors $0 < \beta \leq 1$, and stakeholder discount factors $0 < \theta \leq 1$.*

3 Solving the active ownership identification problem in the context of GHG emissions

In the previous section, we demonstrated the active ownership identification problem where GHG emissions were an inseparable negative externality. GHG emissions, however, are no longer inseparable externalities; firms can invest in mitigation, which reduces and, in some cases, separates GHG emissions from production. Firms can also invest in adaptation to reduce the damage to the firm.[28]

[27] It should be noted that there are no conditions under which all stakeholder-oriented shareholders would increase quantities and emissions. Intuitively, there is always some θ close enough to zero that ensures that the net benefit to stakeholders other than the firm discounted by θ is less than the damage to the firm, so it is always possible that some stakeholder-oriented shareholder decides to decrease quantities, whilst others decide to increase quantities.

[28] For simplicity, we do not allow offsetting in our model. This is possibly an area for future research.

Indeed, two of the papers listed in Section 2 investigating firm-level GHG emissions and institutional investor influence also investigate the effects of institutional investors on investments in mitigation; Akey and Appel (2019) and Naaraayanan et al. (2020).[29] In their sample of hedge funds, Akey and Appel (2019) find no association between hedge fund activism and investments in mitigation. In their sample from the Boardroom Accountability Project ('BAP'), Naaraayanan et al. (2020) find a positive association between BAP environmental activism and investments in mitigation. Similar to Section 2, our question in this section is: with this information, what can we conclude about the active ownership type of the hedge funds and the BAP?

To answer this question, we consider models in which firms can invest in mitigation, m_i, to reduce their net emission is given by $q_i - m_i$, and invest in adaptation, a_i, to reduce the damage to the firm, $\gamma_f(E - a_i)$, simultaneous with their choice of quantities. To make our arguments we compared alternative models to a benchmark model like the one in Section 2, but updated the benchmark model to allow firms to invest in mitigation and adaptation. We refer to this benchmark model as the benchmark mitigation-adaptation model, $BMAM$. We first model the general case, showing that the short-term common owner can be differentiated from other active ownership objectives by no change in investments in mitigation or adaptation relative to the short-term profit maximizer, whilst other active ownership objectives all generate a positive change. This result suggests that the hedge funds in Akey and Appel (2019) may be short-term common owners, whilst those institutional investors associated with the BAP from Naaraayanan et al. (2020) are not short-term common owners. But the result does not necessarily suggest that those institutional investors associated with the BAP from Naaraayanan et al. (2020) can definitely be considered long-term shareholders and/or stakeholder-oriented shareholders, nor are they definitely not long-term common owners or SRIs.[30,31]

To resolve the remaining ambiguity, we then focus on two further industry conditions. The first is when there is no exposure to damage to climate change for firms in Sector Q. In this situation, we find that the long-term profit maximizer will not increase mitigation or

[29]Akey and Appel (2019) and Naaraayanan et al. (2020) refer to mitigation as abatement in their papers.

[30]It should be noted that Naaraayanan et al. (2020) do find a statistically insignificant negative correlation between BAP environmental activism and production. One might be tempted to interpret the statistical insignificance as indicating a low magnitude change in the negative direction, which might suggest the results most support those institutional investors associated with the BAP being either long-term profit maximizers or perhaps even stakeholder-oriented (the latter if this is considered not strong enough evidence to show a reduction, so they could be increasing production). We instead interpret the statistical insignificance as not providing sufficient evidence to resolve the issue, whilst still being consistent with our model.

[31]To be consistent with our treatment of the results from Naaraayanan et al. (2020) in the previous footnote, we also note that whilst Akey and Appel (2019) find no statistically significant correlation between hedge fund activism and mitigation, the correlation is negative. Our modelling does not predict any negative correlations relative to the short-term profit maximizer in the benchmark model. This suggests that the assuming the short-term profit maximizer as the benchmark might be incorrect in the sample of Akey and Appel (2019). Resolving this issue is an area for future research which we discuss in the Discussion and Limitations section.

reduce quantities whilst other active ownership types will. The second is when there is high willingness to pay in Sector Q and revenue varies non-monotonically with quantities.[32]. In this case, the long-term common owner and SRI can be separated based on their impacts on revenue.

3.1 Mitigation and adaptation

3.1.1 The benchmark mitigation-adaptation model

Again, we focus on Sector Q since it is the sector producing emissions. Compared to Section 2.3, we now assume firms in Sector Q aim to maximize short-term profits by choosing mitigation and adaptation as well as quantities. That is, firms simultaneously choose mitigation, m_i, adaptation, a_i, and quantities, q_i, to maximize the following objective:

$$\phi_{STP} = \pi_{Q,i} = (p_Q - c - t)q_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2}, \tag{23}$$

where ρ and ν capture the rate of change of the marginal cost of mitigation and adaptation. It is assumed that units of mitigation in terms of emissions are chosen such that, i.e. $e_i = q_i - m_i$. Furthermore, it is also assumed that one unit of adaptation directly offsets γ_f units of damage, i.e. $\gamma_f(E - a_i)$.[33] For simplicity, we model the choices of mitigation, adaptation and quantity as separable, which will result in equilibrium choices of mitigation, adaptation and quantity being independent of each other. Thus the equilibrium quantities are identical to Equation 18 in Section 2.3.

Given the model set-up, the equilibrium levels of mitigation, $m^*_{i,BMAM}$, and adaptation, $a^*_{i,BMAM}$, are given by:[34]

$$m^*_{i,BMAM} = \frac{t}{\rho}, \tag{24}$$

$$a^*_{i,BMAM} = 0. \tag{25}$$

Note that whilst the short-term profit maximizer does not consider the future damage from climate change, it does some mitigation because of the tax on emissions. In contrast, there is no tax incentive to adapt, so the short-term profit maximizer does not invest in adaptation.

Since $e_i = q_i - m_i$, the equilibrium level of emissions in the benchmark mitigation-adaptation

[32] A condition that holds for all demand curves that intersect both the price and quantity axes

[33] Although, in the case of the short-term profit maximizer, the benefits of adaptation are not considered since the short-term profit maximizer does not consider the damage from emissions in their objective and there is no tax incentivizing adaptation.

[34] See Appendix C.1 for working for the benchmark mitigation-adaptation model.

model will be different to the benchmark model, and is given by:

$$e^*_{i,BMAM} = q^*_{i,BMAM} - m^*_{i,BMAM} = \frac{a-c-t}{3} - \frac{t}{\rho}. \tag{26}$$

3.1.2 Comparison of the alternative mitigation-adaptation models and the benchmark mitigation-adaptation model

In this section, we first present the results associated with mitigation and adaptation, then the results for emissions for the stakeholder-oriented shareholder only. The results for quantities for all active ownership objectives and for emissions for all active ownership objectives other than the stakeholder-oriented shareholder are identical to Propositions 1 and 2 in Section 2.4. The results for quantities are identical since we model choices of mitigation, adaptation and quantities as separable. Whilst emissions now includes mitigation, it will be shown below that mitigation either does not change or increases relative to the benchmark. Since mitigation is negatively related to emissions, recall $e_i = q_i - m_i$, the changes in quantities and mitigation relative to the benchmark mitigation-adaptation model mean that the direction of the changes in emissions relative to the benchmark mitigation-adaptation model are the same as Proposition 1 in Section 2.4. However, the conditions for the stakeholder-oriented shareholder are different to Proposition 2 in the case of emissions, so we also present the emissions-related results for stakeholder-oriented shareholders. We present the mitigation and adaptation results for the stakeholder-oriented shareholder along with the other active ownership objectives.

3.1.2.1 Mitigation and adaptation for all active ownership objectives

The results for mitigation and adaptation for all active ownership objectives is summarized by:[35]

$$m^*_{i,\phi} = \frac{t + \delta\gamma_{\phi,m}}{\rho}, \tag{27}$$

$$a^*_{i,\phi} = \frac{\delta\gamma_{\phi,a}}{\nu}, \tag{28}$$

where ϕ signifies the active ownership objective, m signifies mitigation and a signifies adaptation so that $\gamma_{\phi,m}$ and $\gamma_{\phi,a}$ differ by active ownership objective and between mitigation and adaptation. Specifically, $\delta\gamma_{\phi,m} = \delta\gamma_f$ and $\delta\gamma_{\phi,a} = \delta\gamma_f$ for the long-term profit maximizer, $\delta\gamma_{\phi,m} = 0$ and $\delta\gamma_{\phi,a} = 0$ for the short-term common owner, $\delta\gamma_{\phi,m} = \delta\gamma_{CO}$ and $\delta\gamma_{\phi,a} = \delta\gamma_f$ for the long-term common owner, $\delta\gamma_{\phi,m} = \delta\gamma_{SRI}$ and $\delta\gamma_{\phi,a} = \delta\gamma_f$ for the SRI, and $\delta\gamma_{\phi,m} = \delta\gamma_S$ and $\delta\gamma_{\phi,a} = \delta\gamma_f$ for the stakeholder-oriented shareholder.

[35]See Appendices C.2 to C.6 for the related working.

Since for the short-term profit maximizer $\delta\gamma_{\phi,m} = 0$ and $\delta\gamma_{\phi,a} = 0$, all of the above active ownership types increase mitigation and adaptation relative to the short-term profit maximizer except the short-term common owner. The short-term common owner's investments in mitigation and adaptation are identical to the short-term profit maximizer's.

Proposition 3. *Mitigation and adaptation relative to the benchmark mitigation-adaptation model (that is, the short-term profit maximizer) are:*

i. Higher for the long-term profit maximizer for all time discount factors $0 < \delta \leq 1$*;*

ii. Identical for the short-term common owner for all intra-industry incentives $0 < \lambda_{INTRA} < 1$*;*

iii. Higher for the long-term common owner for all time discount factors $0 < \delta \leq 1$*, intra-industry incentives* $0 < \lambda_{INTRA} < 1$ *and inter-industry incentives* $\lambda_{INTER} > 0$*; and*

iv. Higher for the SRI for all time discount factors $0 < \delta \leq 1$ *and SRI discount factors* $0 < \beta \leq 1$*.*

v. Higher for the stakeholder-oriented shareholder for all time discount factors $0 < \delta \leq 1$ *and stakeholder discount factors* $0 < \theta \leq 1$*.*

These results can be explained using two of the incentives from Section 2.4; the long-term incentive from damage to the firm and the incentive arising from damage to other agents in the model. As the long-term incentive relates to future damage to the firm, those active owners with the long-term incentive (i.e. all active owner types except the short-term common owner) will reduce damage by investing in mitigation and reduce exposure to damage by investing in adaptation relative to the short-term profit maximizer. Those with the incentives arising from damage to other agents in the model (i.e., the SRI, long-term common owner, and stakeholder-oriented shareholder) will further invest in mitigation to reduce damage to the other agents. Finally, since the short-term common owner does not have either of those incentives, they do not mitigate or adapt beyond the amount encouraged by the tax incentives like the short-term profit maximizer.

3.1.2.2 Emissions for stakeholder-oriented shareholders

For the stakeholder-oriented shareholder, emissions is given by:

$$e^*_{i,S} = q^*_{i,S} - m^*_{i,S} = \frac{a - c - t - \delta\gamma_S}{3 - 2\theta} - \frac{t + \delta\gamma_S}{\rho}. \tag{29}$$

Whilst mitigation increases relative to the short-term profit maximizer, the quantities for the stakeholder-oriented shareholder relative to the short-term profit maximizer continue to be ambiguous. Thus, emissions is also ambiguous.[36]

[36]See Appendix C.6.2 for the related working

Proposition 4. *Emissions relative to the benchmark mitigation-adaptation model (that is, the short-term profit maximizer) are lower for the stakeholder-oriented shareholder if and only if the following holds:*

$$\frac{\theta(Q^*_{BMAM} - \delta(\gamma - \gamma_f)) - \delta\gamma_f}{3 - 2\theta} < \frac{\delta\gamma_S}{\rho},$$

where $\gamma_S = \gamma_f + \theta(\gamma - \gamma_f)$ *and* $Q^*_{BMAM} = 2q^*_{BMAM}$

Compared to Proposition 2, the introduction of mitigation adds further complexity to the conditions determining the relative movements. To see this note that for a reduction in emissions to occur the following must hold.

$$q^*_i - q^*_{i,BMAM} = \frac{\theta(Q^*_{BMAM} - \delta(\gamma - \gamma_f)) - \delta\gamma_f}{3 - 2\theta} < \frac{\delta\gamma_S}{\rho} = m^*_i - m^*_{i,BMAM}. \tag{30}$$

Since $m^*_i - m^*_{i,BMAM} > 0$ from Proposition 3, the condition in Proposition 4 is always satisfied if $q^*_i - q^*_{i,BMAM} < 0$. Thus, using the results from Section 2.4.1, Corollary 1 can be expanded to include mitigation.[37]

Corollary 2 (The active ownership identification problem in the context of GHG emissions when firms can mitigate emissions)**.** *If* $Q^*_{BMAM} \leq \delta_S\gamma$, *quantities and emissions relative to the benchmark model are lower for all active ownership objectives for all time discount factors* $0 < \delta \leq 1$, *intra-industry incentives* $0 < \lambda_{INTRA} < 1$, *inter-industry incentives* $\lambda_{INTER} > 0$, *SRI discount factors* $0 < \beta \leq 1$, *and stakeholder discount factors* $0 < \theta \leq 1$.

3.2 Zero exposure to damage

Thus far we have been able to clearly separate the short-term profit maximizer and short-term common owner from the rest, and provide a somewhat fuzzy separation for the stakeholder-oriented shareholder.[38] In this section, we take advantage of the long-term incentive from damage to the firm to suggest a situation in which the long-term shareholder can also be separated. Doing so also introduces cleaner separation conditions for the stakeholder-oriented shareholder. To do so, we analyse the situation when the firm's exposure to damage is zero.[39]

[37]For the same reasons as in footnote 27, there are no conditions under which all stakeholder-oriented shareholders increase quantities and emissions.

[38]This somewhat fuzzy separation is reflected in footnotes 27 and 37. Some stakeholder-oriented shareholders, but not all, may increase quantities and emissions.

[39]Whilst at first glance such conditions may seem counterintuitive, there are some industries and firms that not only have zero exposure but could benefit from climate change. That is, $\gamma_Q < 0$. For example, it is predicted that climate change will lead to increased energy demand (e.g. van Ruijven, De Cian, and Sue Wing, 2019), leading to higher firm-level profits all else equal. Furthermore, it could be argued that whilst perhaps $\gamma_Q \neq 0$, for some firms $\gamma_f e_i \approx 0$ if γ_f and e_i are assumed to be sufficiently small, whilst $\gamma e_i > 0$; these conditions reflect the notion that

To show this, we now assume that firms in Sector Q and Sectors R_n have different exposures to damage, given by γ_Q and γ_{R_n}, and that $\gamma_Q \approx 0$ and $\gamma_{R_n} = \gamma_f$. Since there is no exposure to damage for firms in in Sector Q, we do not consider results related to adaptation in the sections that follow. Finally, we note that the set-up and results for mitigation, adaptation and emissions are identical to Equations 24, 25 and 26, respectively, in Section 3.1.1.

We first focus on the results for mitigation and then the results for quantities and emissions. For mitigation, we follow a similar structure to Section 3.1.2 by presenting results for all active ownership objectives together. For quantities and emissions, we follow a similar structure to Section 2.4 by presenting two sets of results due to the complexity of the results for the stakeholder-oriented shareholder.

3.2.1 Mitigation

The expression for equilibrium mitigation is the same as Equation 27, however now $\delta\gamma_f = 0$ for all active owner types. Thus, the results for mitigation for all active ownership objectives can be summarized by the following proposition.

Proposition 5. *If the firm is not exposed to damage, then mitigation relative to the benchmark mitigation-adaptation model (that is, the short-term profit maximizer) are:*

i. Identical for the long-term profit maximizer for all time discount factors $0 < \delta \leq 1$;

ii. Identical for the short-term common owner for all intra-industry incentives $0 < \lambda_{INTRA} < 1$;

iii. Higher for the long-term common owner for all time discount factors $0 < \delta \leq 1$, *intra-industry incentives* $0 < \lambda_{INTRA} < 1$ *and inter-industry incentives* $\lambda_{INTER} > 0$; *and*

iv. Higher for the SRI for all time discount factors $0 < \delta \leq 1$ *and SRI discount factors* $0 < \beta \leq 1$.

v. Higher for the stakeholder-oriented shareholder for all time discount factors $0 < \delta \leq 1$ *and stakeholder discount factors* $0 < \theta \leq 1$.

Compared to Proposition 3, it can now be seen that the long-term profit maximizer does not increase mitigation relative to the short-term profit maximizer. For the remaining active ownership objectives, the results in Proposition 5 are identical to those in Proposition 3.

These results are driven by whether an incentive to mitigate arises from considering damage to other agents in the model. As noted above, the long-term incentive arising from damage to the firm has been removed by assuming exposure to damage is zero. Thus, the long-term profit maximizer has no incentive beyond the tax incentive to invest in mitigation like

a firm's emissions barely impact its own profits, but cause non-zero damage in total. Under such conditions, the results from this section remain.

the short-term profit maximizer and the short-term common owner. The long-term common owner, SRI and stakeholder-oriented shareholder, however, all have incentives to mitigate arising from damage to other agents in the model; the long-term common owner to reduce damage to their investments in other sectors, the SRI and the stakeholder-oriented shareholder to reduce damage to all other agents.

3.2.2 Quantities and emissions of all active ownership objectives except stakeholder

The expression for equilibrium quantities is the same as Equation 20, however now $\delta\gamma_f = 0$ for all active owner types. Thus, results for quantities and emissions for all active ownership objectives except stakeholder-oriented shareholders can be summarized by the following proposition.

Proposition 6. *If the firm is not exposed to damage, quantities and emissions relative to the benchmark model (that is, the short-term profit maximizer) are:*

i. Identical for the long-term profit maximizer for all time discount factors $0 < \delta \leq 1$*;*

ii. Lower for the short-term common owner for all intra-industry incentives $0 < \lambda_{INTRA} < 1$*;*

iii. Lower for the long-term common owner for all time discount factors $0 < \delta \leq 1$*, intra-industry incentives* $0 < \lambda_{INTRA} < 1$ *and inter-industry incentives* $\lambda_{INTER} > 0$*; and*

iv. Lower for the SRI for all time discount factors $0 < \delta \leq 1$ *and SRI discount factors* $0 < \beta \leq 1$*.*

In contrast to Proposition 1, the long-term profit maximizer now sets quantities and emissions identical to the short-term profit maximizer. The results for other active ownership objectives are identical to Proposition 1. Since the long-term incentive arising from damage to the firm has been removed, the long-term profit maximizer has no incentive to reduce quantities or increase mitigation relative to the short-term profit maximizer. Since $e_i = q_i - m_i$, the long-term profit maximizer therefore also does not reduce emissions relative to the short-term profit maximizer. Those with the other active ownership objectives either have the intra-industry common ownership incentive, which incentivizes a reduction in quantities, or the incentive arising from damage to agents other than the firm in the model, which incentivizes both a reduction in quantities and increase in mitigation. Thus, the other active ownership objectives will reduce quantities and emissions relative to the short-term profit maximizer.

3.2.3 Quantities and emissions of stakeholder-oriented shareholders

The expression for equilibrium quantities for the stakeholder-oriented shareholder is the same as Equation 21. However, now $\delta\gamma_f = 0$. The results for quantities for stakeholder-oriented shareholders are summarized by the following proposition.

Proposition 7. *If the firm is not exposed to damage, then quantities relative to the benchmark mitigation-adaptation model (that is, the short-term profit maximizer) are lower [higher] for the stakeholder-oriented shareholder for all* $0 < \theta \leq 1$ *when [the converse of]* $Q^*_{BM} < \delta\gamma$ *holds where* $Q^*_{BM} = 2q^*_{i,BM}$.

Again, in contrast to the other active ownership objectives and similar to Proposition 2, the stakeholder-oriented shareholder does not necessarily reduce quantities relative to the short-term profit maximizer. However, in contrast to footnotes 27 and 37, by Proposition 7 there are now conditions under which the stakeholder-oriented shareholder unambiguously increases quantities. Since the firm is no longer exposed to damage, the stakeholder-oriented shareholder is no longer trading off the damage to the firm against the net benefit to stakeholders other than the firm. Thus, stakeholder-oriented shareholder's decision to expand or reduce production is entirely based on whether the net benefit to stakeholders other than the firm, $Q^*_{BM} - \delta\gamma$,[40] is greater or less than zero.

The expression for equilibrium emissions for the stakeholder-oriented shareholder is the same as Equation 29. However, now $\delta\gamma_f = 0$. The results for emissions for stakeholder-oriented shareholders are summarized by the following proposition.[41]

Proposition 8. *If the firm is not exposed to damage, then emissions relative to the benchmark mitigation-adaptation model (that is, the short-term profit maximizer) are lower [higher] for the stakeholder-oriented shareholder if and only if [the converse of]* $\theta < \theta^*(\delta)$ *holds, which is true for all* $0 < \theta \leq 1$ *when* $Q^*_{BM} - \delta\gamma < \frac{\delta\gamma}{\rho}$ *[*$Q^*_{BMAM} - \delta\gamma > 3\frac{\delta\gamma}{\rho}$*] where* $\theta^*(\delta) = \frac{3}{2} - \frac{Q^*_{BMAM} - \delta\gamma}{2\frac{\delta\gamma}{\rho}}$.

The explanation for Proposition 8 is similar to Proposition 4, however, now $\gamma_Q \approx 0$. Substituting $\gamma_Q = 0$ into the condition from Proposition 4 yields:

$$q^*_i - q^*_{i,BMAM} = \frac{\theta(Q^*_{BMAM} - \delta\gamma)}{3 - 2\theta} < \theta\frac{\delta\gamma}{\rho} = m^*_i - m^*_{i,BMAM}. \tag{31}$$

Thus, the stakeholder-oriented shareholder reduces emissions if the incentive to mitigate is larger than the incentive to expand production, and vice versa. Also, by again noting $0 < \theta \leq 1$, conditions under which all stakeholder-oriented shareholders will either increase or decrease emissions can be derived.

These results mean that Corollary 2 can be expanded to include the case where firms are not exposed to damage from GHG emissions, but changed to account for the differing results for the long-term profit maximizer.

[40] The expression is identical to that in Proposition 2, except now $\gamma_Q = 0$ so that $\gamma = \gamma - \gamma_Q$.

[41] See Appendix C.6.3 for working.

Corollary 3 (The active ownership identification problem in the context of GHG emissions when firms can mitigate emissions and firms are not exposed to damage)**.** *When firms can invest in mitigation to reduce emissions, if $Q^*_{BMAM} \leq \delta_S\gamma$ and the firm is not exposed to damage from GHG emissions, quantities and emissions relative to the benchmark model are lower for all active ownership objectives, except the long-term profit maximizer, for all time discount factors $0 < \delta \leq 1$, intra-industry incentives $0 < \lambda_{INTRA} < 1$, inter-industry incentives $\lambda_{INTER} > 0$, SRI discount factors $0 < \beta \leq 1$, and stakeholder discount factors $0 < \theta \leq 1$.*

In contrast to Corollaries 1,2,3, however, there are conditions under which all stakeholder-oriented shareholders will increase quantities and emissions when the firm is not exposed to damage from GHG emissions.

Corollary 4. *When firms can invest in mitigation to reduce emissions, if $Q^*_{BMAM} - \delta_S\gamma > 3\frac{\delta_S\gamma}{\rho}$ and the firm is not exposed to damage from GHG emissions, quantities and emissions relative to the benchmark model are higher for stakeholder-oriented shareholders for all stakeholder discount factors $0 < \theta \leq 1$.*

3.3 High willingness to pay and non-monotone revenue

We now separate the long-term common owner from the SRI as these are the only remaining active ownership objectives for which separation conditions have not been derived. However, to do so we require a new measure from the model. It can be seen in the results so far that, under our model and assumptions, the long-term common owner moves the firm in identical directions to the SRI in terms of quantities, emissions, investments in mitigation and investments in adaptation. Therefore, these measures cannot be directly used to produce a separation so we require a new outcome from the model.

We focus on revenue for two reasons, one pragmatic and one technical. The pragmatic reason is that revenue is a widely available measure and is therefore available for empirical work. Furthermore, our model can be considered a relatively accurate representation for revenue, whereas other measures available from our model and empirically, such as profit, might reasonably be significantly affected by many factors not in our model.[42]

The technical reason is that in some circumstances revenue is not a monotone function of quantities. [43] Thus, whilst quantities for the long-term common owner and SRI are always

[42]Nonetheless, one could, qualitatively speaking, replicate the results based on revenue below for other non-monotonic functions of choice variables since the key factor driving the result is non-monotonicity.

[43]It is important to note, however, that such an assumption is not satisfied by CES utility functions.

lower than the short-term profit maximizer, the same does not apply for revenue; it is possible for a reduction in quantities[44] to produce either an increase or decrease in revenue.[45] We illustrate this graphically in Figure 1 below. If willingness to pay, represented by a in our model, is low, then equilibrium quantities are to the left of the revenue maximization point as indicated by the yellow circle in Figure 1a. As a result, a reduction in quantities always results in a decrease in revenue. But if willingness to pay is high, then equilibrium quantities for the short-term profit maximizer are to the right of the revenue maximization point as indicated by the orange circle in Figure 1b. In this case, a reduction in quantities can produce either an increase or decrease in revenue, depending on the magnitude of the change in quantities. Therefore, when willingness to pay is high, the effect of decreasing quantities on revenue is somewhat ambiguous.

We exploit this property of the revenue function when willingness to pay is high to separate the long-term common owner from the SRI under the additional requirement that inter-industry common ownership is high.[46] Here is it important to note that we now put a subscript on δ to indicate the active ownership objective to which δ belongs. That is:[47]

Proposition 9. *If* $a \geq 4(c+t) + 2\delta_{SRI}\gamma$ *and* $\lambda_{INTER} \geq \frac{\delta_{SRI}}{\delta_{CO}}\frac{\gamma}{\gamma_f} - 1$, *then revenue relative to the benchmark mitigation-adaptation model (that is, the short-term profit maximizer) is:*

i Lower for the long-term common owner for all intra-industry common ownership incentives $0 < \lambda_{INTRA} < 1$; *and*

ii. Higher for the SRI for all SRI discount factors $0 < \beta \leq 1$.

The intuition behind Proposition 9 is that both active owner types have an incentive to reduce quantities due to the damage from GHG emissions to agents other than the firm. However, the SRIs incentive is capped ($\beta \leq 1$) whilst the long-term common owner's incentive is not capped ($\lambda_{INTER} > 0$). Thus, one can find conditions under which the incentive is larger for the long-term common owner than the SRI. We find that if willingness to pay is high enough, then mark-ups are high and as a result the marginal profit from an additional unit of production may balance the marginal damage from climate change for the SRI such that the SRI will not reduce revenue even though they are reducing quantities. On the other hand, under conditions of high mark-ups, a common owner might still prefer a decrease in quantities sufficiently large to result in a decrease in revenue if their inter-industry ownership is sufficiently large.

We highlight, however, that the long-term common owner has not been fully differenti-

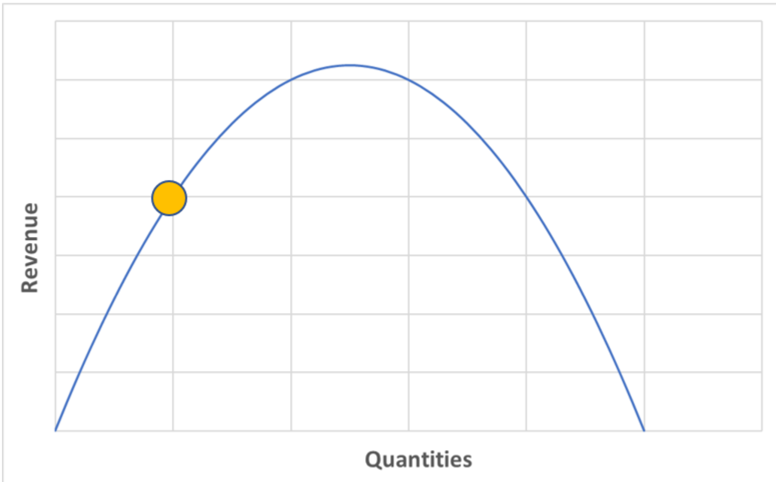
[44]We focus on a reduction in quantities because a reduction in quantities occurs for each active owner type compared to the benchmark models under our model and assumptions.

[45]See Appendix C.7.1 and C.7.2 for working related to this point

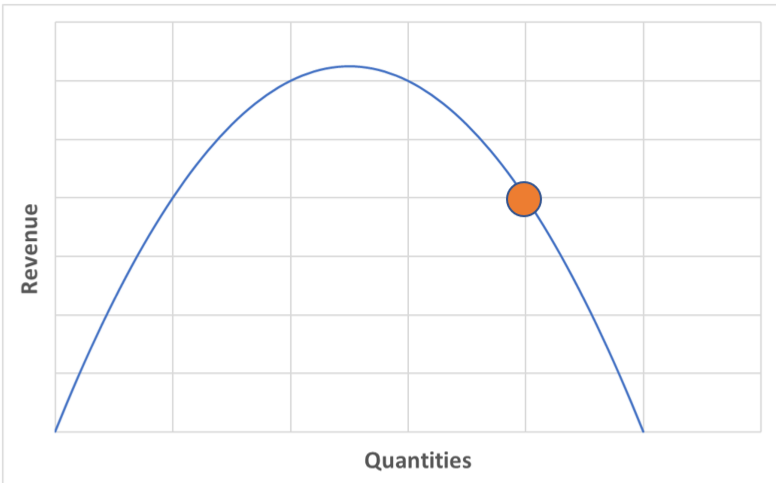
[46]See Appendices C.7.3 to C.7.11 for working related to this point.

[47]For this specific Proposition, see Appendix C.7.3, C.7.4 and C.7.5

Figure 1: Revenue and the location of the benchmark model quantities based on willingness to pay. Note that the revenue curves depend on willingness to pay so are not the same between the panels



(a) The position of equilibrium benchmark model quantity on the revenue curve when willingness to pay is low



(b) The position of equilibrium benchmark model quantity on the revenue curve when willingness to pay is high ated from the SRI. The separation derived above between the long-term common owner and SRI occurs only for high levels of inter-industry common ownership. In Appendices C.7.3 to C.7.11, we present results where the conditions are independent of the level of common ownership, depend on the level of intra-industry common ownership, and depend on both intra- and inter-industry common ownership. [48] Thus, finding empirically pragmatic separation conditions at any level of common ownership is an important area for future research on the active ownership identification problem.

4 Conclusion

In the preceding sections, we demonstrated the active ownership identification problem in the context of firm-level GHG emissions. We then presented one solution to this problem by analyzing the outcomes of our model under different industry conditions to separate different active ownership objectives. Our solution is summarized in Figure 2 below.

Our solution is subject to limitations, some of which offer interesting areas for future research. We have made several simplifying assumptions in our model. Here we discuss the impact of relaxing some those assumptions.[49] The first of these assumptions relates to our mathematical representation of damage from emissions and the relationship between quantities, mitigation, and adaptation. We have assumed that damage is linear in emissions, mitigation and adaptation, and that choices of quantities, mitigation and adaptation are independent of each other.[50] Relaxing these assumptions may change the equilibrium values and values of the industry conditions for separations. However, we do not believe that relaxing these assumptions would change the direction of the movement in equilibrium values nor the qualitative statements about the industry conditions required for separations. Therefore, our key results would be maintained.

The second of these assumptions relates to the individual characteristics of consumer-workers, firms and institutional investors. We have assumed a linear demand function and constant marginal costs. Our key results would be maintained under general demand and

[48]Of these conditions, those in Proposition 9 seemed to strike the best balance between understand-ability and empirical applicability. However, the results under the conditions which depend on common ownership are similar to those presented in Proposition 9: if willingness to pay is high, common ownership is sufficiently high, and revenue is a non-monotonic function of quantities, then the long-term common owner will reduce revenue whilst the SRI will not. This separation, however, still only occurs for sufficiently high common ownership rather than any level of common ownership.

[49]See footnotes 17, 19, 23, 39, 43 and the final paragraph of Section 3.3 for discussions of other assumptions.

[50]It is sometimes assumed in the literature that damage is a quadratic function of emissions and that the cross partial derivatives with respect to quantities, mitigation and adaptation are not zero such that the choices of each affect each other.

Figure 2: Movements in model outcomes for each active ownership objective relative to the short-term profit maximizer under different industry conditions. Results separating active ownership objectives are underlined. See Sections 2.4.2, 3.1.2, 3.2 and 3.3 for further details on the industry conditions required for each result.

Industry conditions	Viability of mitigation and adaptation, and exposure to damage from emissions						Willingness to pay is high and revenue is a non-monotonic function of quantities	
	Mitigation & Adaptation: NO Exposure: YES		Mitigation & Adaptation: YES Exposure: YES		Mitigation & Adaptation: YES Exposure: NO			
Active ownership objectives / **Model outcomes**	Quantities	Emissions	Quantities (Mitigation)	Emissions (Adaptation)	Quantities (Mitigation)	Emissions (Adaptation)	Quantities	Revenue
Long-term profit maximizer	Decrease	Decrease	Decrease (Increase)	Decrease (Increase)	None (None)	None (None)	-	-
Short-term common owner	Decrease	Decrease	Decrease (None)	Decrease (None)	Decrease (None)	Decrease (None)	-	-
Long-term common owner	Decrease	Decrease	Decrease (Increase)	Decrease (Increase)	Decrease (Increase)	Decrease (Increase)	Decrease	Decrease
SRI	Decrease	Decrease	Decrease (Increase)	Decrease (Increase)	Decrease (Increase)	Decrease (Increase)	Decrease	Increase
Stakeholder-oriented shareholder*	Decrease Or Increase	Decrease Or Increase	Decrease (Increase) Or Increase (Increase)	Decrease (Increase) Or Increase (Increase)	Decrease (Increase) Or Increase (Increase)	Decrease (Increase) Or Increase (Increase)	-	-

cost functions for the same reasons as in the previous paragraph. An exception is Proposition 9, which relies on demand functions with revenue curves that are non-monotonic functions of quantities. Further, we have assumed the discount rates and incentives that appear in many of the institutional investors' possible active ownership objectives are not common across active ownership objectives. However, assuming common time discount rates is not unusual in other literatures. In Appendix D.1, we present results where we assume that active ownership objectives have a common but unknown time discount factor or intra-industry common ownership incentive. However, to remain faithful to our research question investigating unknown, possibly heterogeneous objective functions we do not present these results in the body of this paper.

The third of these assumptions relates to the assumed benchmark model. To simplify our analysis, we create a benchmark model rather than using control weights between a benchmark and other objectives. We then assume (short-term) profit maximization as the firm objective in the benchmark model. This assumption appears to be the (perhaps implicit) assumption across the theoretical literatures on active ownership objectives.[51] Such an assumption, however, is unlikely to be empirically plausible since, in addition to the one institutional investor which is the focus of this paper, many economic agents (other shareholders, workers, consumers, management, directors, regulators etc.) may influence the corporate objective, for example, due to agency problems.[52] We see gaining further understanding of and overcoming this benchmark problem as a key area for future research that aims to solve the active ownership identification problem in natural experimental settings.

The last of these assumptions relates to our corporate governance process, with which there are two further limitations. First, it might appear that the corporate governance process modelled does not match the key independent variable in the empirical literature, ownership. The empirical literature on social responsibility predominantly uses ownership as an independent variable (e.g. Gillan et al., 2021). The common ownership literature, whilst predominantly using measures of common ownership incentives as independent variables (e.g.

[51]The common ownership literature (e.g. Azar and Vives, 2021) uses an objective function consisting of individual firm profits and other firms' profits, where the degree to which other firms' profits are considered is given by λ. If $\lambda = 0$, such an objective reduces to profit maximization. The CSR and SRI literature (e.g. Hart and Zingales, 2017; Broccardo et al., 2020) uses an objective function consisting of profits and damage from an externality, where the degree to which damage from a firm's activities is considered is given by λ. If $\lambda = 0$, such an objective also reduces to profit maximization. The literature that most closely resembles stakeholder theory (e.g. Magill et al., 2015) uses a weighted objective function of profits and consumer or worker utility, where the weighting given to consumer or worker utility is given by θ. If $\theta = 0$, such an objective again reduces to profit maximization.

[52]Important in relation to this point and as noted in a previous footnote, the results of our paper do not entirely explain the results in Akey and Appel (2019). They find a statistically insignificant negative correlation between hedge fund activism and mitigation. However, our paper does not predict a negative change in mitigation for any active ownership type relative to the short-term profit maximizer. Our suspicion, which is somewhat corroborated by the discussion in Akey and Appel (2019) about the profit-oriented nature of hedge funds, is that the benchmark is not profit maximisation in the sample of Akey and Appel (2019).

Schmalz, 2018, 2021), has used ownership as a independent variable in the context of firm-level GHG emissions (e.g. Azar et al., 2021). By using ownership as an independent variable, the dependent variable can be seen as a weighted function of shareholder preferences over the dependent variable, where the weighting is ownership and the regression coefficients are the shareholder preferences. In a model that is simplified to two distinct groups of sincere shareholders who share control over firm-level choices, the first derivative of the weighted function of shareholder preferences with respect to one shareholder's ownership, and thus the regression coefficient on this shareholder's ownership, is the difference between the two shareholder's preferences.[53]. This difference has been the subject of our analysis throughout the paper. Thus, whilst not appearing to match the approach of the empirical literature, we do indeed model the approach in the empirical literature on active ownership objectives. Second, whilst we do follow the approach of the empirical literature, the corporate governance process we have modelled is relatively simple. Such a simplified model may not be empirically plausible for the same reasons as in the previous paragraph. Exploring the implications of the design of the corporate governance process is another important area for future research on the active ownership identification problem.

Finally, we believe this paper has considerable implications for academics, practitioners, regulators and policymakers. The active ownership identification problem in the context of firm-level GHG emissions sits at the nexus of greenwashing and financial product promises more broadly,[54] competition policy and facilitating a just transition. As noted at the outset of the paper, institutional investor's active ownership policies may contain promises to influence firms on particular issues, such as climate change, in accordance with a particular active ownership objective. But the focus of greenwashing to the best of our knowledge has been on whether institutional investor influence is used to address the issue of climate change, not whether influence is used in accordance with the promised or implied active ownership objective. Would or should, say, a consumer or provider of a financial product care if outcomes were improved through SRI versus common ownership? Such a question also highlights the implications for competition regulation and policy. Is an action socially responsible or is the cloak of social responsibility being donned for anticompetitive (common ownership) purposes? Finally, in light of skewed corporate equity ownership exacerbating inequality and the possible relation to common ownership (e.g. Gans et al., 2019), it might be asked; which objective is most consistent with (the promise of) facilitating a just transition? In answering these questions, it will be of import to solve the active ownership identification problem.

[53]See Appendix D.2

[54]Through, for example, the environmental promises made in institutional investors' active ownership policies.

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Appendices

Appendix A Model set-up

A.1 Profits of Sector Y and wages

The profits of a firm in Sector Y is given by:

$$\pi_Y = p_Y y - wL_y. \tag{32}$$

Since y is the numeraire, $p_Y = 1$. Since competition in Sector Y is perfect, $\pi_Y = 0$. Noting the production function for firms in Sector Y is $Y = L_y$ so that the marginal cost of labor per unit of of production of Y, $\frac{\partial L_Y}{\partial Y}$, is $\frac{\partial L_Y}{\partial Y} = 1$, it follows that:

$$\pi_Y = p_Y y - wL_y = y - wy = 0, \tag{33}$$

which implies the wage rate, w, is $w = 1$.

A.2 Long-term profit expressions for Sector Q and Sectors R_n

The long-term profit for firm i in Sector Q is given by:

$$\tilde{\pi}_{Q,i} = p_Q q_i - wL_Q - te_i - \delta\gamma_f E. \tag{34}$$

Now since $w = 1$ and noting that the marginal cost of of labor per unit of production, $\frac{\partial L_Q}{\partial Q}$, is $\frac{\partial L_Q}{\partial Q} = c$, the profit function can be written as:

$$\tilde{\pi}_{Q,i} = p_Q q_i - cq_i - te_i - \delta\gamma_f E. \tag{35}$$

A similar line of reasoning can be followed to derive the profit function of firms in Sectors R_n.

A.3 Demand functions

representative consumer aims to maximise its utility:

$$U_j(Q_j, R_{n,j}, y_j) = y_j - \delta\gamma_{cw}E + aQ_j - \frac{Q_j^2}{2} + \sum_n aR_{n,j} - \frac{R_{n,j}^2}{2} \tag{36}$$

subject to the constraint $wLj \geq y_j + p_Q Q_j + \sum_n p_{R_n} R_{n,j}$. The Langrangian, $\mathcal{L}$, of the constrained maximisation problem is given by:

$$\mathcal{L} = U_j(Q_j, R_{n,j}, y_j) + \varphi(wLj - y_j - p_Q Q_j - \sum_n p_{R_n} R_{n,j}). \tag{37}$$

Taking the first order condition with respect to φ gives the binding budget constraint:

$$\frac{\partial \mathcal{L}}{\partial \varphi} = wLj - y_j - p_Q Q_j - \sum_n p_{R_n} R_{n,j} = 0 \implies wLj = y_j + p_Q Q_j + \sum_n p_{R_n} R_{n,j}. \tag{38}$$

The first order condition with respect to y_j gives φ:

$$\frac{\partial \mathcal{L}}{\partial y_j} = 1 - \varphi = 0 \implies \varphi = 1. \tag{39}$$

The first order condition with respect to Q_j is given by:

$$\frac{\partial \mathcal{L}}{\partial Q_j} = a - Q_j - \varphi p_Q = 0 \implies Q_j = a - p_Q. \tag{40}$$

Noting that $E = E_0 + Q$ and, due to the unit mass assumption, $Q = \int_0^1 Q_j \; dj$ so that $\frac{\partial E}{\partial Q_j} = \frac{\partial Q}{\partial Q_j} = 0$. This solution is a global maximizer. Since the utility function is strictly quasiconcave and the budget constraint is convex, there is a unique global constrained maximizer. Since the first order conditions result in a unique solution, this solution must be the global maximizer.

Finally, demand for good q in Sector Q is therefore given by:

$$Q = \int_0^1 Q_j \; dj = \int_0^1 a - p_Q \; dj = a - p_Q, \tag{41}$$

where it is assumed $a > Q$ so that $p_Q > 0$.

A similar line of reasoning can be followed to derive the demand functions in Sectors R_n.

A.4 Emissions tax

Assume the government aims to implement a socially optimal emissions tax assuming firms are short-term profit maximizers (i.e., in the benchmark model. See Appendix B.1). To find the socially optimal tax, we find the socially optimal market quantity that maximizes welfare in the absence of taxes, then equate the socially optimal market quantity to the total market quantity with taxes. Since welfare is maximized when prices equal marginal costs, it follows that:

$$p_Q^* = c + \delta\gamma \implies Q^* = a - c - \delta\gamma. \tag{42}$$

Thus, to derive the socially optimal tax:

$$Q^* = Q_{BM}^* \implies t^* = \frac{1}{2}(3\delta\gamma - (a - c)), \tag{43}$$

where $Q_{BM}^* = 2q_i^*$. Note that t^* can be negative or positive. A negative t^* indicates a subsidy. This arises because there are two distortions in the market; imperfect competition and the negative externality. To ensure $t^* > 0$ assume:

$$a < c + 3\delta\gamma. \tag{44}$$

Appendix B Models for Section 2

B.1 The benchmark model

A Nash equilibrium is found by firm i choosing quantities, q_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\phi_{STP} &= \pi_{Q,i} \\ &= (p_Q - c)q_i - te_i \qquad (45)\\ &= (a - q_i - q_{-i} - c - t)q_i \qquad (46)\end{aligned}$$

since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, and $q_i = e_i$. The first order condition is given by:

$$\frac{\partial \phi_{STP}}{\partial q_i} = a - 2q_i - q_{-i} - c - t = 0 \tag{47}$$

and thus, whilst noting $\frac{\partial^2 \phi_{STP}}{\partial q_i^2} = -2 < 0$ so that the solution is a maximum, the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - q_{-i} - c - t}{2}. \tag{48}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - c - t}{3}, \tag{49}$$

where it is assumed $a > c + t$ so that $q_i^* > 0$.

B.2 Long-term profit maximizer

A Nash equilibrium is found by firm i choosing quantities, q_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\phi_{LTP} &= \tilde{\pi}_{Q,i} \\ &= \pi_{Q,i} - \delta\gamma_f E \\ &= (a - q_i - q_{-i} - c - t - \delta\gamma_f)q_i - \delta\gamma_f(E_0 + q{-}i) \\ &= (a - q_i - q_{-i} - \tilde{c})q_i - \delta\gamma_f(E_0 + q{-}i),\end{aligned} \tag{50}$$

where $\tilde{c} = c + t + \delta\gamma_f$, and since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e{-}i$, and $q_i = e_i$. The first order condition is given by:

$$\frac{\partial \phi_{LTP}}{\partial q_i} = a - 2q_i - q_{-i} - \tilde{c} = 0 \tag{51}$$

and thus, whilst noting $\frac{\partial^2 \phi_{LTP}}{\partial q_i^2} = -2 < 0$ so that the solution is a maximum, the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - q_{-i} - \tilde{c}}{2}. \tag{52}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - \tilde{c}}{3} = \frac{a - c - t - \delta\gamma_f}{3}, \tag{53}$$

where it is assumed $a > c + t + \delta\gamma_f$ so that $q_i^* > 0$.

B.3 Short-term common owner

A Nash equilibrium is found by firm i choosing quantities, q_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\tilde{\phi}_{STCO} &= \pi_{Q,i} + \lambda_{INTRA,Q}\pi_{Q,-i} + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,k_n} + \lambda_{INTRA,R_n}\pi_{R_n,-k_n}) \\ &= (a - q_i - q_{-i} - c - t)(q_i + \lambda_{INTRA,Q}q_{-i}) \\ &\quad + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,k_n} + \lambda_{INTRA,R_n}\pi_{R_n,-k_n})\end{aligned} \tag{54}$$

since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, and $q_i = e_i$. The first order condition is given by:

$$\frac{\partial\tilde{\phi}_{STCO}}{\partial q_i} = a - 2q_i - q_{-i} - c - t - \lambda_{INTRA}q_{-i} = 0 \tag{55}$$

and thus, whilst noting $\frac{\partial^2\tilde{\phi}_{STCO}}{\partial q_i^2} = -2 < 0$ so that the solution is a maximum, the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - (1 + \lambda_{INTRA})q_{-i} - c - t}{2}. \tag{56}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - c - t}{3 + \lambda_{INTRA}}, \tag{57}$$

where it is assumed $a > c + t$ so that $q_i^* > 0$.

B.4 Long-term common owner

A Nash equilibrium is found by firm i choosing quantities, q_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\tilde{\phi}_{LTCO} &= \pi_{Q,i} + \lambda_{INTRA,Q}\pi_{Q,-i} + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,k_n} + \lambda_{INTRA,R_n}\pi_{R_n,-k_n}) - \delta\gamma_{CO}E \\ &= (a - q_i - q_{-i} - c - t)(q_i + \lambda_{INTRA,Q}q_{-i}) - \delta\gamma_{CO}q_i \\ &\quad + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,k_n} + \lambda_{INTRA,R_n}\pi_{R_n,-k_n}) \\ &\quad - \delta\gamma_{CO}(E_0 + q_{-i})\end{aligned} \tag{58}$$

since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e{-i}$, and $q_i = e_i$. The first order condition is given by:

$$\frac{\partial \tilde{\phi}_{LTCO}}{\partial q_i} = a - 2q_i - q_{-i} - c - t - \lambda_{INTRA} q_{-i} - \delta\gamma_{CO} = 0 \tag{59}$$

and thus, whilst noting $\frac{\partial^2 \tilde{\phi}_{LTCO}}{\partial q_i^2} = -2 < 0$ so that the solution is a maximum, the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - (1 + \lambda_{INTRA})q_{-i} - c - t - \delta\gamma_{CO}}{2}. \tag{60}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - c - t - \delta\gamma_{CO}}{3 + \lambda_{INTRA}}, \tag{61}$$

where it is assumed $a > c + t + \delta\gamma_{CO}$ so that $q_i^* > 0$.

B.5 SRI

A Nash equilibrium is found by firm i choosing quantities, q_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\phi_{SRI} &= \pi_{Q,i} - \delta\gamma_{SRI} E \\ &= (a - q_i - q_{-i} - \tilde{c})q_i - \delta\gamma_f(E_0 + q{-i}),\end{aligned}$$

where $\tilde{c} = c + t + \delta\gamma_{SRI}$, and since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e{-i}$, and $q_i = e_i$. The first order condition is given by:

$$\frac{\partial \phi_{SRI}}{\partial q_i} = a - 2q_i - q_{-i} - \tilde{c} = 0 \tag{62}$$

and thus, whilst noting $\frac{\partial^2 \phi_{SRI}}{\partial q_i^2} = -2 < 0$ so that the solution is a maximum, the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - q_{-i} - \tilde{c}}{2}. \tag{63}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - \tilde{c}}{3} = \frac{a - c - t - \delta\gamma_{SRI}}{3}, \tag{64}$$

where it is assumed $a > c + t + \delta\gamma_{SRI}$ so that $q_i^* > 0$.

B.6 Stakeholder-oriented shareholder

B.6.1 Equilibrium quantities

A Nash equilibrium is found by firm i choosing quantities, q_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}
\phi_S &= \pi_{Q,i} + \theta U_{cw}(Q, R_n, y) - \delta\gamma_S E \\
&= (a - q_i - q_{-i} - c)q_i - te_i \\
&\quad + \theta(y + aQ - \frac{Q^2}{2} + \sum_n aR_n - \frac{R_n^2}{2}) \\
&\quad - \delta\gamma_S E \\
&= (a - q_i - q_{-i} - \tilde{c})q_i \\
&\quad + \theta(wL - p_Q Q - \sum_n p_{R_n} R_n + aQ - \frac{Q^2}{2} + \sum_n aR_n - \frac{R_n^2}{2}) \\
&\quad - \delta\gamma_S(E_0 + q_{-i}) \\
&= (a - q_i - q_{-i} - \tilde{c})q_i + \theta\frac{(q_i + q_{-i})^2}{2} \\
&\quad + \theta(wL + \sum_n \frac{R_n^2}{2}) \\
&\quad - \delta\gamma_S(E_0 + q_{-i}),
\end{aligned} \tag{65}$$

where $\tilde{c} = c + t + \delta\gamma_S$, assuming the budget constraint binds such that $y = wL - p_Q Q - \sum_n p_{R_n} R_n$, and since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e{-}i$, and $q_i = e_i$. The first order condition is given by:

$$\frac{\partial \phi_S}{\partial q_i} = a - 2q_i - q_{-i} - \tilde{c} + \theta(q_i + q_{-i}) = 0 \tag{66}$$

and thus, whilst noting $\frac{\partial^2 \phi_{SRI}}{\partial q_i^2} = -2 + \theta < 0$ for any $0 < \theta \leq 1$ so that the solution is a maximum, the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - (1-\theta)q_{-i} - \tilde{c}}{2 - \theta}. \tag{67}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - \tilde{c}}{3 - 2\theta} = \frac{a - c - t - \delta\gamma_S}{3 - 2\theta}, \tag{68}$$

where it is assumed $a > c+t+\delta\gamma_S$ so that $q_i^* > 0$. Note that $0 < \theta \leq 1$ implies the denominator is always positive.

B.6.2 Conditions that ensure the quantity choice by the stakeholder-oriented shareholder is less than the quantity choice in the benchmark model

The following condition must be satisfied:

$$q_{i,S}^* < q_{i,BM}^* \implies \frac{a-c-t-\delta\gamma_S}{3-2\theta} < \frac{a-c-t}{3}. \tag{69}$$

Rearranging:

$$3(a-c-t-\delta\gamma_S) < (3-2\theta)(a-c-t) \implies \delta\gamma_S > \theta Q_{BM}^* \implies \delta\gamma_f > \theta(Q_{BM}^* - \delta(\gamma-\gamma_f)), \tag{70}$$

where $Q_{BM}^* = 2q_{BM}^*$, $\delta\gamma_S = \delta\gamma_f + \delta\theta(\gamma-\gamma_f)$ and $\gamma = NI\gamma_f + \gamma_{cw}$. Now this condition will always be true if $Q_{BM}^* - \delta(\gamma-\gamma_f) < 0$ since $\gamma_f > 0$. Assuming $Q_{BM}^* - \delta(\gamma-\gamma_f) > 0$ and rearranging for θ:

$$\theta < \frac{\delta\gamma_f}{Q_{BM}^* - \delta(\gamma-\gamma_f)}. \tag{71}$$

Since $0 < \theta \leq 1$, this condition is always true if the right-hand side is greater than or equal to 1:

$$\frac{\delta\gamma_f}{Q_{BM}^* - \delta(\gamma-\gamma_f)} \geq 1 \implies Q_{BM}^* \leq \delta\gamma, \tag{72}$$

noting that the implication follows only if $Q_{BM}^* - \delta(\gamma-\gamma_f) > 0$, which was assumed at the outset.

B.6.3 No conditions that ensure the quantity choice by the stakeholder-oriented shareholder is greater than the quantity choice in the benchmark model

The following condition must be satisfied:

$$q_{i,S}^* > q_{i,BM}^* \implies \frac{a-c-t-\delta\gamma_S}{3-2\theta} > \frac{a-c-t}{3}. \tag{73}$$

Rearranging:

$$3(a-c-t-\delta\gamma_S) > (3-2\theta)(a-c-t) \implies \delta\gamma_S < \theta Q_{BM}^* \implies \delta\gamma_f < \theta(Q_{BM}^* - \delta(\gamma-\gamma_f)), \tag{74}$$

where $Q_{BM}^* = 2q_{BM}^*$, $\delta\gamma_S = \delta\gamma_f + \delta\theta(\gamma-\gamma_f)$ and $\gamma = NI\gamma_f + \gamma_{cw}$. Now this condition will cannot be true if $Q_{BM}^* - \delta(\gamma-\gamma_f) < 0$ since $\gamma_f > 0$. Assuming $Q_{BM}^* - \delta(\gamma-\gamma_f) > 0$ and rearranging for θ:

$$\theta > \frac{\delta\gamma_f}{Q^*_{BM} - \delta(\gamma - \gamma_f)}. \tag{75}$$

Since $0 < \theta \leq 1$, this condition is always true if the right-hand side is less than or equal to 0:

$$\frac{\delta\gamma_f}{Q^*_{BM} - \delta(\gamma - \gamma_f)} \leq 0 \implies \delta\gamma_f \leq 0, \tag{76}$$

which contradicts $\gamma_f > 0$. Thus there are no conditions that guarantee the stakeholder-oriented shareholder chooses a higher level of quantities than the choice in the benchmark model.

Appendix C Models for Section 3

C.1 The benchmark mitigation-adaptation model

A Nash equilibrium is found by firm i choosing quantities, q_i, mitigation, m_i, and adaptation, a_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\phi_{STP} &= \pi_{Q,i} \\ &= (p_Q - c)q_i - te_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\ &= (a - q_i - q_{-i} - c - t)q_i + tm_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2}\end{aligned} \tag{77}$$

since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, and $e_i = q_i - m_i$. The first order condition with respect to q_i is given by:

$$\frac{\partial \phi_{STP}}{\partial q_i} = a - 2q_i - q_{-i} - c - t = 0 \tag{78}$$

and thus the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - q_{-i} - c - t}{2}. \tag{79}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - c - t}{3}, \tag{80}$$

where it is assumed $a > c + t$ so that $q_i^* > 0$. The first order condition with respect to m_i is given by:

$$\frac{\partial \phi_{STP}}{\partial m_i} = t - \rho m_i = 0 \tag{81}$$

and thus equilibrium mitigation is given by:

$$m_i^* = \frac{t}{\rho}. \tag{82}$$

The first order condition with respect to a_i is given by:

$$\frac{\partial \phi_{STP}}{\partial m_i} = -\nu a_i = 0 \tag{83}$$

and thus equilibrium adaptation is given by:

$$a_i^* = 0. \tag{84}$$

Finally, note that the Hessian matrix is given by:

$$H(q_i, m_i, a_i) = \begin{pmatrix} -2 & 0 & 0 \\ 0 & -\rho & 0 \\ 0 & 0 & -\nu \end{pmatrix}, \tag{85}$$

which is negative definite at (q_i^*, m_i^*, a_i^*). Therefore (q_i^*, m_i^*, a_i^*) is a maximum. Since it is unique and the objective function is concave, it is the global maximum.

C.2 Long-term profit maximizer with mitigation and adaptation

A Nash equilibrium is found by firm i choosing quantities, q_i, mitigation, m_i, and adaptation, a_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned} \phi_{LTP} &= \tilde{\pi}_{Q,i} \\ &= \pi_{Q,i} - \delta\gamma_f(E - a_i) \\ &= (p_Q - c)q_i - te_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} - \delta\gamma_f(E - a_i) \\ &= (a - q_i - q_{-i} - \tilde{c})q_i + (t + \delta\gamma_f)m_i + \delta\gamma_f a_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} - \delta\gamma_f(E_0 + q - i), \end{aligned} \tag{86}$$

where $\tilde{c} = c + t + \delta\gamma_f$, and since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e_{-i}$, and $e_i = q_i - m_i$. The first order condition for quantities is given by:

$$\frac{\partial \phi_{LTP}}{\partial q_i} = a - 2q_i - q_{-i} - \tilde{c} = 0 \tag{87}$$

and thus the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - q_{-i} - \tilde{c}}{2}. \tag{88}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - \tilde{c}}{3} = \frac{a - c - t - \delta\gamma_f}{3}, \tag{89}$$

where it is assumed $a > c + t + \delta\gamma_f$ so that $q_i^* > 0$. The first order condition with respect to m_i is given by:

$$\frac{\partial \phi_{LTP}}{\partial m_i} = t + \delta\gamma_f - \rho m_i = 0 \tag{90}$$

and thus equilibrium mitigation is given by:

$$m_i^* = \frac{t + \delta\gamma_f}{\rho}. \tag{91}$$

The first order condition with respect to a_i is given by:

$$\frac{\partial \phi_{LTP}}{\partial m_i} = \delta\gamma_f - \nu a_i = 0 \tag{92}$$

and thus equilibrium adaptation is given by:

$$a_i^* = \frac{\delta\gamma_f}{\nu}. \tag{93}$$

Finally, note that the Hessian matrix is given by:

$$H(q_i, m_i, a_i) = \begin{pmatrix} -2 & 0 & 0 \\ 0 & -\rho & 0 \\ 0 & 0 & -\nu \end{pmatrix}, \tag{94}$$

which is negative definite at (q_i^*, m_i^*, a_i^*). Therefore (q_i^*, m_i^*, a_i^*) is a maximum. Since it is unique and the objective function is concave, it is the global maximum.

C.3 Short-term common owner with mitigation and adaptation

A Nash equilibrium is found by firm i choosing quantities, q_i, mitigation, m_i, and adaptation, a_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\tilde{\phi}_{STCO} &= \pi_{Q,i} + \lambda_{INTRA,Q}\pi_{Q,-i} \\ &\qquad + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,i} + \lambda_{INTRA,R_n}\pi_{R_n,-i}) \\ &\qquad - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\ &= (a - q_i - q_{-i} - c - t)(q_i + \lambda_{INTRA,Q}q_{-i}) + tm_i \\ &\qquad + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,i} + \lambda_{INTRA,R_n}\pi_{R_n,-i}) \\ &\qquad - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2}\end{aligned} \tag{95}$$

since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, and $e_i = q_i - m_i$. The first order condition is given by:

$$\frac{\partial\tilde{\phi}_{STCO}}{\partial q_i} = a - 2q_i - q_{-i} - c - t - \lambda_{INTRA}q_{-i} = 0 \tag{96}$$

and thus the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - (1 + \lambda_{INTRA})q_{-i} - c - t}{2}. \tag{97}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - c - t}{3 + \lambda_{INTRA}}, \tag{98}$$

where it is assumed $a > c + t$ so that $q_i^* > 0$. The first order condition with respect to m_i is given by:

$$\frac{\partial\tilde{\phi}_{STCO}}{\partial m_i} = t - \rho m_i = 0 \tag{99}$$

and thus equilibrium mitigation is given by:

$$m_i^* = \frac{t}{\rho}. \tag{100}$$

The first order condition with respect to a_i is given by:

$$\frac{\partial\tilde{\phi}_{STCO}}{\partial m_i} = -\nu a_i = 0 \tag{101}$$

and thus equilibrium adaptation is given by:

$$a_i^* = 0. \tag{102}$$

Finally, note that the Hessian matrix is given by:

$$H(q_i, m_i, a_i) = \begin{pmatrix} -2 & 0 & 0 \\ 0 & -\rho & 0 \\ 0 & 0 & -\nu \end{pmatrix}, \tag{103}$$

which is negative definite at (q_i^*, m_i^*, a_i^*). Therefore (q_i^*, m_i^*, a_i^*) is a maximum. Since it is unique and the objective function is concave, it is the global maximum.

C.4 Long-term common owner with mitigation and adaptation

A Nash equilibrium is found by firm i choosing quantities, q_i, mitigation, m_i, and adaptation, a_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}
\tilde{\phi}_{LTCO} &= \pi_{Q,i} + \lambda_{INTRA,Q}\pi_{Q,-i} + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,i} + \lambda_{INTRA,R_n}\pi_{R_n,-i}) \\
&\quad - \delta\gamma_f(E - a_i) - \delta(\gamma_{CO} - \gamma_f)E \\
&= (a - q_i - q_{-i} - c)q_i - te_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\
&\quad + \lambda_{INTRA,Q}((a - q_i - q_{-i} - c)q_{-i} - te_{-i} - \frac{\rho m_{-i}^2}{2} - \frac{\nu a_{-i}^2}{2}) \\
&\quad + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,i} + \lambda_{INTRA,R_n}\pi_{R_n,-i}) \\
&\quad - \delta\gamma_f(E - a_i) - \delta(\gamma_{CO} - \gamma_f)E \\
&= (a - q_i - q_{-i} - c - t)(q_i + \lambda_{INTRA,Q}q_{-i}) - \delta\gamma_{CO}q_i \\
&\quad + (t + \delta\gamma_{CO})m_i + \delta\gamma_f a_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\
&\quad + \lambda_{INTRA,Q}(tm_{-i} - \frac{\rho m_{-i}^2}{2} - \frac{\nu a_{-i}^2}{2}) \\
&\quad + \sum_n \lambda_{INTER,R_n}(\pi_{R_n,i} + \lambda_{INTRA,R_n}\pi_{R_n,-i}) \\
&\quad - \delta\gamma_f(E_0 + q_{-i}) - \delta(\gamma_{CO} - \gamma_f)(E_0 + q_{-i})
\end{aligned} \tag{104}$$

since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e_{-i}$, and $e_i = q_i - m_i$. The first order condition is given by:

$$\frac{\partial\tilde{\phi}_{LTCO}}{\partial q_i} = a - 2q_i - q_{-i} - c - t - \lambda_{INTRA}q_{-i} - \delta\gamma_{CO} = 0 \tag{105}$$

and thus the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - (1 + \lambda_{INTRA})q_{-i} - c - t - \delta\gamma_{CO}}{2}. \tag{106}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - c - t - \delta\gamma_{CO}}{3 + \lambda_{INTRA}}. \tag{107}$$

where it is assumed $a > c + t + \delta\gamma_{CO}$ so that $q_i^* > 0$. The first order condition with respect to m_i is given by:

$$\frac{\partial\tilde{\phi}_{LTCO}}{\partial m_i} = t + \delta\gamma_{CO} - \rho m_i = 0 \tag{108}$$

and thus equilibrium mitigation is given by:

$$m_i^* = \frac{t + \delta\gamma_{CO}}{\rho}. \tag{109}$$

The first order condition with respect to a_i is given by:

$$\frac{\partial\tilde{\phi}_{LTP}}{\partial m_i} = \delta\gamma_f - \nu a_i = 0 \tag{110}$$

and thus equilibrium adaptation is given by:

$$a_i^* = \frac{\delta\gamma_f}{\nu}. \tag{111}$$

Finally, note that the Hessian matrix is given by:

$$H(q_i, m_i, a_i) = \begin{pmatrix} -2 & 0 & 0 \\ 0 & -\rho & 0 \\ 0 & 0 & -\nu \end{pmatrix}, \tag{112}$$

which is negative definite at (q_i^*, m_i^*, a_i^*). Therefore (q_i^*, m_i^*, a_i^*) is a maximum. Since it is unique and the objective function is concave, it is the global maximum.

C.5 SRI with mitigation and adaptation

A Nash equilibrium is found by firm i choosing quantities, q_i, mitigation, m_i, and adaptation, a_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}\phi_{SRI} &= \pi_{Q,i} - \delta\gamma_f(E - a_i) - \delta(\gamma_{SRI} - \gamma_f)E \\ &= (a - q_i - q_{-i} - \tilde{c})q_i + (t + \delta\gamma_{SRI})m_i + \delta\gamma_f a_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\ &\quad - \delta\gamma_f(E_0 + q{-}i) - \delta(\gamma_{SRI} - \gamma_f)(E_0 + q{-}i),\end{aligned} \tag{113}$$

where $\tilde{c} = c + t + \delta\gamma_{SRI}$, and since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e{-}i$, and $q_i = e_i - m_i$. The first order condition is given by:

$$\frac{\partial \phi_{SRI}}{\partial q_i} = a - 2q_i - q_{-i} - \tilde{c} = 0 \tag{114}$$

and thus the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - q_{-i} - \tilde{c}}{2}. \tag{115}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - \tilde{c}}{3} = \frac{a - c - t - \delta\gamma_{SRI}}{3}, \tag{116}$$

where it is assumed $a > c + t + \delta\gamma_{SRI}$ so that $q_i^* > 0$. The first order condition with respect to m_i is given by:

$$\frac{\partial \phi_{SRI}}{\partial m_i} = t + \delta\gamma_{SRI} - \rho m_i = 0 \tag{117}$$

and thus equilibrium mitigation is given by:

$$m_i^* = \frac{t + \delta\gamma_{SRI}}{\rho}. \tag{118}$$

The first order condition with respect to a_i is given by:

$$\frac{\partial \phi_{SRI}}{\partial m_i} = \delta\gamma_f - \nu a_i = 0 \tag{119}$$

and thus equilibrium adaptation is given by:

$$a_i^* = \frac{\delta\gamma_f}{\nu}. \tag{120}$$

Finally, note that the Hessian matrix is given by:

$$H(q_i, m_i, a_i) = \begin{pmatrix} -2 & 0 & 0 \\ 0 & -\rho & 0 \\ 0 & 0 & -\nu \end{pmatrix}, \tag{121}$$

which is negative definite at (q_i^*, m_i^*, a_i^*). Therefore (q_i^*, m_i^*, a_i^*) is a maximum. Since it is unique and the objective function is concave, it is the global maximum.

C.6 Stakeholder-oriented shareholder

C.6.1 Equilibrium quantities, mitigation and adaptation

A Nash equilibrium is found by firm i choosing quantities, q_i, mitigation, m_i, and adaptation, a_i, taking the other firm's quantities, q_{-i}, as given to maximise:

$$\begin{aligned}
\phi_S &= \pi_{Q,i} + \theta U_{cw}(Q, R_n, y) - \delta\gamma_f(E - a_i) - \delta(\gamma_S - \gamma_f)E \\
&= (a - q_i - q_{-i} - c)q_i - te_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\
&\quad + \theta(y + aQ - \frac{Q^2}{2} + \sum_n aR_n - \frac{R_n^2}{2}) \\
&\quad - \delta\gamma_f(E - a_i) - \delta(\gamma_S - \gamma_f)E \\
&= (a - q_i - q_{-i} - \tilde{c})q_i + (t + \delta\gamma_S)m_i + \delta\gamma_f a_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\
&\quad + \theta(wL - p_Q Q - \sum_n p_{R_n} R_n + aQ - \frac{Q^2}{2} + \sum_n aR_n - \frac{R_n^2}{2}) \\
&\quad - \delta\gamma_f(E_0 + q_{-i}) - \delta(\gamma_S - \gamma_f)(E_0 + q_{-i}) \\
&= (a - q_i - q_{-i} - \tilde{c})q_i + \theta\frac{(q_i + q_{-i})^2}{2} + (t + \delta\gamma_S)m_i + \delta\gamma_f a_i - \frac{\rho m_i^2}{2} - \frac{\nu a_i^2}{2} \\
&\quad + \theta(wL + \sum_n \frac{R_n^2}{2}) \qquad (122) \\
&\quad - \delta\gamma_f(E_0 + q_{-i}) - \delta(\gamma_S - \gamma_f)(E_0 + q_{-i}),
\end{aligned}$$

where $\tilde{c} = c + t + \delta\gamma_S$, assuming the budget constraint binds such that $y = wL - p_Q Q - \sum_n p_{R_n} R_n$, and since $p_Q = a - Q = a - q_i - q_{-i}$ and $a > Q$ so that $p_Q > 0$, $E = E_0 + e_i + e{-}i$, and $e_i = q_i - m_i$. The first order condition for quantities is given by:

$$\frac{\partial \phi_S}{\partial q_i} = a - 2q_i - q_{-i} - \tilde{c} + \theta(q_i + q_{-i}) = 0 \tag{123}$$

and thus the best response function is given by:

$$R_i(q_{-i}) = q_i = \frac{a - (1-\theta)q_{-i} - \tilde{c}}{2-\theta}. \tag{124}$$

By noting the symmetry of firms implies $q_i^* = q_{-i}^*$, equilibrium quantity is given by:

$$q_i^* = \frac{a - \tilde{c}}{3 - 2\theta} = \frac{a - c - t - \delta\gamma_S}{3 - 2\theta}, \tag{125}$$

where it is assumed $a > c + t + \delta\gamma_S$ so that $q_i^* > 0$. Note that $0 < \theta \leq 1$ implies the denominator is always positive. The first order condition with respect to m_i is given by:

$$\frac{\partial \phi_S}{\partial m_i} = t + \delta\gamma_S - \rho m_i = 0 \tag{126}$$

and thus equilibrium mitigation is given by:

$$m_i^* = \frac{t + \delta\gamma_S}{\rho}. \tag{127}$$

The first order condition with respect to a_i is given by:

$$\frac{\partial \phi_S}{\partial m_i} = \delta\gamma_f - \nu a_i = 0 \tag{128}$$

and thus equilibrium adaptation is given by:

$$a_i^* = \frac{\delta\gamma_f}{\nu}. \tag{129}$$

Finally, note that the Hessian matrix is given by:

$$H(q_i, m_i, a_i) = \begin{pmatrix} -2+\theta & 0 & 0 \\ 0 & -\rho & 0 \\ 0 & 0 & -\nu \end{pmatrix}, \tag{130}$$

which is negative definite at (q_i^*, m_i^*, a_i^*). Therefore (q_i^*, m_i^*, a_i^*) is a maximum. Since it is unique and the objective function is concave, it is the global maximum.

C.6.2 Conditions that ensure the emissions by the stakeholder-oriented shareholder are less than the emissions in the benchmark model

The following condition must be satisfied:

$$q_{i,S}^* - m_{i,S}^* < q_{i,BMAM}^* - m_{i,BMAM}^* \implies q_{i,S}^* - q_{i,BMAM}^* < m_{i,S}^* - m_{i,BMAM}^*. \tag{131}$$

Substituting and rearranging:

$$\frac{a-c-t-\delta\gamma_S}{3-2\theta} - \frac{a-c-t}{3} < \frac{t+\delta\gamma_S}{\rho} - \frac{t}{\rho}$$

$$\implies \frac{3(a-c-t-\delta\gamma_S)-(3-2\theta)(a-c-t)}{3(3-2\theta)} < \frac{\delta\gamma_S}{\rho}. \tag{132}$$

Thus:

$$\frac{\theta(Q^*_{BMAM}-\delta(\gamma-\gamma_f))-\delta\gamma_f}{3-2\theta} < \frac{\delta\gamma_S}{\rho}, \tag{133}$$

where $Q^*_{BMAM} = 2q^*_{BMAM}$, $\delta\gamma_S = \delta\gamma_f + \delta\theta(\gamma-\gamma_f)$ and $\gamma = NI\gamma_f + \gamma_{cw}$.

The condition to ensure emissions for the stakeholder-oriented shareholder are higher than in the benchmark model is then the converse of the above condition.

C.6.3 Conditions that ensure the emissions by the stakeholder-oriented shareholder are less than the emissions in the benchmark model when firms are not exposed to damage from emissions

The following condition must be satisfied for a decrease in emissions:

$$q^*_{i,S} - m^*_{i,S} < q^*_{i,BMAM} - m^*_{i,BMAM} \implies q^*_{i,S} - q^*_{i,BMAM} < m^*_{i,S} - m^*_{i,BMAM}, \tag{134}$$

which is the same as Appendix C.6.2. Substituting $\delta\gamma_Q = 0$:

$$\frac{\theta(Q^*_{BMAM}-\delta\gamma))}{3-2\theta} < \frac{\theta\delta\gamma}{\rho} \implies \theta\left(\frac{Q^*_{BMAM}-\delta\gamma}{3-2\theta} - \frac{\delta\gamma}{\rho}\right) < 0, \tag{135}$$

where $Q^*_{BMAM} = 2q^*_{BMAM}$, $\delta\gamma_S = \delta\gamma_f + \delta\theta(\gamma-\gamma_f)$ and $\gamma = NI\gamma_f + \gamma_{cw}$. Since $\theta > 0$, for the condition to hold it must be that:

$$\frac{Q^*_{BMAM}-\delta\gamma}{3-2\theta} - \frac{\delta\gamma}{\rho} < 0 \implies \theta < \frac{3}{2} - \frac{Q^*_{BMAM}-\delta\gamma}{2\frac{\delta\gamma}{\rho}}. \tag{136}$$

Since $0 < \theta \leq 1$, this is always true if the right-side is greater than or equal to 1:

$$\frac{3}{2} - \frac{Q^*_{BMAM}-\delta\gamma}{2\frac{\delta\gamma}{\rho}} \geq 1 \implies Q^*_{BMAM} - \delta\gamma < \frac{\delta\gamma}{\rho}. \tag{137}$$

Thus, if this condition holds, then the stakeholder-oriented shareholder is guaranteed to reduce emissions. Following similar lines of reasoning, the following condition must hold for an increase in emissions:

$$\theta > \frac{3}{2} - \frac{Q^*_{BMAM} - \delta\gamma}{2\frac{\delta\gamma}{\rho}}. \tag{138}$$

Since $0 < \theta \leq 1$, this is always true if the right-side is less than 0:

$$\frac{3}{2} - \frac{Q^*_{BMAM} - \delta\gamma}{2\frac{\delta\gamma}{\rho}} < 0 \implies Q^*_{BMAM} - \delta\gamma > 3\frac{\delta\gamma}{\rho}. \tag{139}$$

Thus, if this condition holds, then the stakeholder-oriented shareholder is guaranteed to increase emissions.

C.7 Separating the long-term common owner and the SRI

C.7.1 The equilibrium revenue maximization point and conditions under which the point is less than the equilibrium quantities in the benchmark model

Equilibrium revenue for firm i in the benchmark mitigation-adaptation model is given by:

$$p^*_Q q^*_i = (a - 2q^*_i)q^*_i \tag{140}$$

since $q^*_i = q^*_{-i}$. The first-order condition for the equilibrium quantity that maximises equilibrium revenue (the 'equilibrium revenue maximization point') is given by:

$$a - 4q^*_i = 0 \implies q^*_{i,RevMax} = \frac{a}{4}, \tag{141}$$

noting that the second derivative is negative so $q^*_{i,RevMax}$ is indeed a maximum. Now, the equilibrium quantities from the benchmark model, $q_{i,BMAM}$, will be greater than the amount that maximises revenue, $q_{i,RevMax}$, if:

$$q^*_{i,RevMax} < q^*_{i,BMAM} \implies \frac{a}{4} < \frac{a - c - t}{3} \implies a > 4(c + t). \tag{142}$$

Thus, if $a > 4(c + t)$, then equilibrium quantities in the benchmark model will be to the right of the equilibrium quantity that maximises revenue.

C.7.2 The benchmark-model-equivalent revenue point

Assuming $a > 4(c + t)$, the benchmark-model-equivalent revenue point can be found by noting that the revenue curve is symmetric, and therefore the distance between the benchmark-model-equivalent revenue point and the equilibrium revenue maximization point must be equal to the distance between the equilibrium revenue maximization point and the benchmark model equilibrium firm-level quantities. The distance between benchmark model equilibrium firm-level quantities and the equilibrium revenue maximization point is given by:

$$\frac{a-c-t}{3} - \frac{a}{4} = \frac{a-4(c+t)}{12}. \tag{143}$$

Therefore, the equivalent revenue point is given by:

$$q^*_{i,ERP} = \frac{a}{4} - \frac{a-4(c+t)}{12} = \frac{a+2(c+t)}{6}. \tag{144}$$

C.7.3 No decrease in revenue for the SRI

The SRI will not decrease revenue if the SRI's equilibrium quantities are greater than or equal to the equivalent equilibrium revenue point:

$$q^*_{i,SRI} \geq q^*_{i,ERP} \implies \frac{a-c-t-\delta\gamma_{SRI}}{3} \geq \frac{a+2(c+t)}{6} \implies \beta \leq \frac{a-2\delta\gamma_f-4(c+t)}{2\delta(\gamma-\gamma_f)}. \tag{145}$$

Since $0 < \beta \leq 1$, the latter condition always holds if the right hand side is greater than or equal to 1:

$$\frac{a-2\delta\gamma_f-4(c+t)}{2\delta(\gamma-\gamma_f)} \geq 1 \implies a \geq 4(c+t) + 2\delta\gamma. \tag{146}$$

Thus, the SRI will not decrease revenue if $a \geq 4(c+t) + 2\delta\gamma$.

C.7.4 Decrease in revenue for the LTCO in terms of inter-industry common ownership

The long-term common owner will decrease revenue if the long-term common owner's equilibrium quantities are less than the equivalent equilibrium revenue point:

$$q^*_{i,LTCO} < q^*_{i,ERP} \implies \frac{a-c-t-\delta\gamma_{CO}}{3+\lambda_{INTRA}} < \frac{a+2(c+t)}{6}, \tag{147}$$

which implies:

$$\lambda_{INTRA} > \frac{3a-12(c+t)-6\delta\gamma_f(1+\lambda_{INTER})}{a+2(c+t)+6\delta\gamma_f(1+\lambda_{INTER})}. \tag{148}$$

Since $0 < \lambda_{INTRA} < 1$, the latter condition always holds if the right hand side is less than or equal to 0:

$$\frac{3a-12(c+t)-6\delta\gamma_f(1+\lambda_{INTER})}{a+2(c+t)+6\delta\gamma_f(1+\lambda_{INTER})} \leq 0 \implies a \leq 4(c+t) + 2\delta\gamma_f(1+\lambda_{INTER}). \tag{149}$$

C.7.5 Conditions separating the long-term common owner and SRI in terms of inter-industry common ownership

The SRI will not decrease revenue if $a \geq 4(c+t) + 2\delta_{SRI}\gamma$. The long-term common owner will decrease revenue if $a \leq 4(c+t) + 2\delta_{LTCO}\gamma_f(1+\lambda_{INTER})$ for any $0 < \lambda_{INTRA} < 1$. Therefore, the SRI will not decrease revenue and the long-term common owner will decrease revenue if:

$$4(c+t)+2\delta_{SRI}\gamma \leq a \leq 4(c+t)+2\delta_{LTCO}\gamma_f(1+\lambda_{INTER}) \implies \lambda_{INTER} \geq \frac{\delta_{SRI}}{\delta_{LTCO}}\frac{\gamma}{\gamma_f} - 1. \quad (150)$$

Thus, if $a \geq 4(c+t) + 2\delta_{SRI}\gamma$ and $\lambda_{INTER} \geq \frac{\delta_{SRI}\gamma}{\delta_{LTCO}\gamma_f} - 1$, then the SRI does not decrease revenue and the long-term common owner with any $0 < \lambda_{INTRA} < 1$ does decrease revenue.

C.7.6 Decrease in revenue for the LTCO in terms of intra-industry common ownership

The long-term common owner will decrease revenue if the long-term common owner's equilibrium quantities are less than the equivalent equilibrium revenue point:

$$q^*_{i,LTCO} < q^*_{i,ERP} \implies \frac{a-c-t-\delta\gamma_{CO}}{3+\lambda_{INTRA}} < \frac{a+2(c+t)}{6}, \quad (151)$$

which implies:

$$\lambda_{INTER} > \frac{3a - 12(c+t) - 6\delta\gamma_f(1+\lambda_{INTRA}) - \lambda_{INTRA}(a+2(c+t))}{6\delta\gamma_f(1+\lambda_{INTRA})}. \quad (152)$$

Since $\lambda_{INTER} > 0$, this condition is always true if the right hand side is less than or equal to 0:

$$\frac{3a - 12(c+t) - 6\delta\gamma_f(1+\lambda_{INTRA}) - \lambda_{INTRA}(a+2(c+t))}{6\delta\gamma_f(1+\lambda_{INTRA})} \leq 0, \quad (153)$$

which implies:

$$3a - 12(c+t) - 6\delta\gamma_f(1+\lambda_{INTRA}) - \lambda_{INTRA}(a+2(c+t)) \leq 0 \quad (154)$$

$$\implies (3-\lambda_{INTRA})a - 2(6+\lambda_{INTRA})(c+t) - 6\delta\gamma_f(1+\lambda_{INTRA}) \leq 0 \quad (155)$$

$$\implies a \leq \frac{2(6+\lambda_{INTRA})(c+t) + 6\delta\gamma_f(1+\lambda_{INTRA})}{3-\lambda_{INTRA}}. \quad (156)$$

C.7.7 Conditions separating the long-term common owner and SRI in terms of intra-industry common ownership

The SRI will not decrease revenue if $a \geq 4(c+t) + 2\delta_{SRI}\gamma$. The long-term common owner will decrease revenue if $a \leq \frac{2(6+\lambda_{INTRA})(c+t)+6\delta\gamma_f(1+\lambda_{INTRA})}{3-\lambda_{INTRA}}$ for any $\lambda_{INTER} > 0$. Therefore, the SRI will not decrease revenue and the long-term common owner will decrease revenue if:

$$4(c+t) + 2\delta_{SRI}\gamma \leq a \leq \frac{2(6+\lambda_{INTRA})(c+t) + 6\delta\gamma_f(1+\lambda_{INTRA})}{3-\lambda_{INTRA}}, \tag{157}$$

which implies:

$$\lambda_{INTRA} \geq \frac{3(\delta_{SRI}\gamma - \delta_{LTCO}\gamma_f)}{3(c+t) + 3\delta_{LTCO}\gamma_f + \delta_{SRI}\gamma} \tag{158}$$

$$= \frac{3(\delta_{SRI}\gamma - \delta_{LTCO}\gamma_f)}{3(\delta_{SRI}\gamma - \delta_{LTCO}\gamma_f) + 3(c+t) + 6\delta_{LTCO}\gamma_f - 2\delta_{SRI}\gamma}. \tag{159}$$

Thus, if $a \geq 4(c+t) + 2\delta_{SRI}\gamma$ and $\lambda_{INTRA} \geq \frac{3(\delta_{SRI}\gamma - \delta_{LTCO}\gamma_f)}{3(\delta_{SRI}\gamma - \delta_{LTCO}\gamma_f)+3(c+t)+6\delta_{LTCO}\gamma_f - 2\delta_{SRI}\gamma}$, then the SRI does not decrease revenue and the long-term common owner with any $\lambda_{INTER} > 0$ does decrease revenue.

C.7.8 Decrease in revenue for the LTCO in terms of intra- and inter-industry common ownership

The long-term common owner will decrease revenue if the long-term common owner's equilibrium quantities are less than the equivalent equilibrium revenue point:

$$q^*_{i,LTCO} < q^*_{i,ERP} \implies \frac{a-c-t-\delta\gamma_{CO}}{3+\lambda_{INTRA}} < \frac{a+2(c+t)}{6}, \tag{160}$$

which implies:

$$a < \frac{2(6+\lambda_{INTRA})(c+t) + 6\delta\gamma_{CO}}{3-\lambda_{INTRA}}. \tag{161}$$

C.7.9 Conditions separating the long-term common owner and SRI in terms of intra- and inter-industry common ownership

The SRI will not decrease revenue if $a \geq 4(c+t) + 2\delta_{SRI}\gamma$. The long-term common owner will decrease revenue if $a < \frac{2(6+\lambda_{INTRA})(c+t)+6\delta\gamma_{CO}}{3-\lambda_{INTRA}}$. Therefore, the SRI will not decrease revenue and the long-term common owner will decrease revenue if:

$$4(c+t)+2\delta_{SRI}\gamma \leq a < \frac{2(6+\lambda_{INTRA})(c+t)+6\delta\gamma_{CO}}{3-\lambda_{INTRA}} \tag{162}$$

$$\implies \frac{3(\lambda_{INTRA}(c+t)+\delta_{LTCO}\gamma_{CO})}{3-\lambda_{INTRA}} > \delta_{SRI}\gamma. \tag{163}$$

Thus, if $a \geq 4(c+t)+2\delta_{SRI}\gamma$ and $\frac{3(\lambda_{INTRA}(c+t)+\delta_{LTCO}\gamma_{CO})}{3-\lambda_{INTRA}} > \delta_{SRI}\gamma$, then the SRI does not decrease revenue and the long-term common owner does decrease revenue.

C.7.10 Decrease in revenue for the LTCO for any level of common ownership

The long-term common owner will decrease revenue if the long-term common owner's equilibrium quantities are less than the equivalent equilibrium revenue point:

$$q^*_{i,LTCO} < q^*_{i,ERP} \implies \frac{a-c-t-\delta\gamma_{CO}}{3+\lambda_{INTRA}} < \frac{a+2(c+t)}{6}, \tag{164}$$

which implies:

$$\lambda_{INTRA} > \frac{3a-12(c+t)-6\delta\gamma_f(1+\lambda_{INTER})}{a+2(c+t)+6\delta\gamma_f(1+\lambda_{INTER})} \tag{165}$$

Since $0 < \lambda_{INTRA} < 1$, the latter condition always holds if the right hand side is less than or equal to 0:

$$\frac{3a-12(c+t)-6\delta\gamma_f(1+\lambda_{INTER})}{a+2(c+t)+6\delta\gamma_f(1+\lambda_{INTER})} \leq 0 \implies a \leq 4(c+t)+2\delta\gamma_f(1+\lambda_{INTER}). \tag{166}$$

Thus, the long-term common owner will decrease revenue if $a \leq 4(c+t)+2\delta\gamma_f(1+\lambda_{INTER})$. That is, if:

$$\lambda_{INTER} \geq \frac{a-4(c+t)-2\delta\gamma_f}{2\delta\gamma_f}. \tag{167}$$

Since $\lambda_{INTER} > 0$, this condition always holds if the right hand side is less than or equal to zero:

$$\frac{a-4(c+t)-2\delta\gamma_f}{2\delta\gamma_f} \leq 0 \implies a \leq 4(c+t)-2\delta\gamma_f. \tag{168}$$

C.7.11 Conditions separating the long-term common owner and SRI for any level of common ownership

The SRI will not decrease revenue if $a \geq 4(c+t)+2\delta_{SRI}\gamma$. The long-term common owner will decrease revenue if $a \leq 4(c+t) + 2\delta_{LTCO}\gamma_f$ for any $0 < \lambda_{INTRA} < 1$ and any $\lambda_{INTER} > 0$. Therefore, the SRI will not decrease revenue and the long-term common owner will decrease revenue if:

$$4(c+t) + 2\delta_{SRI}\gamma \leq a \leq 4(c+t) + 2\delta_{LTCO}\gamma_f \implies \frac{\delta_{SRI}}{\delta_{LTCO}} \frac{\gamma}{\gamma_f} \leq 1. \tag{169}$$

Thus, if $a \geq 4(c+t) + 2\delta_{SRI}\gamma$ and $\frac{\delta_{SRI}}{\delta_{LTCO}} \frac{\gamma}{\gamma_f} \leq 1$, then the SRI does not decrease revenue and the long-term common owner with any $0 < \lambda_{INTRA} < 1$ and any $\lambda_{INTER} > 0$ does decrease revenue.

Appendix D Discussion and limitations

D.1 Further results assuming a common discount factor or common intra-industry incentive

Since some active ownership objectives contain more than one of the incentives above, if it is assumed that these incentives are identical across objectives, the following results also arise:

Proposition 10. *Assuming a common time discount factor, δ,quantities and emissions relative to the alternative where firms are long-term profit maximizers are:*

i. Lower for the long-term common owner for all intra-industry incentives $0 < \lambda_{INTRA} < 1$ and inter-industry incentives $\lambda_{INTER} > 0$; and

ii. Lower for the SRI for all SRI discount factors $0 < \beta \leq 1$.

Proposition 11. *Assuming a common intra-industry incentive, λ_{INTRA}, quantities and emissions relative to the alternative model where firms have a short-term common owner objective are lower for the long-term common owner for all time discount factors $0 < \delta \leq 1$ inter-industry incentives $\lambda_{INTER} > 0$.*

Proposition 12. *Assuming a common time discount factor, δ, mitigation relative to the alternative mitigation-adaptation model where firms have a long-term profit objective are:*

i. Higher for the long-term common owner for all intra-industry incentives $0 < \lambda_{INTRA} < 1$ and inter-industry incentives $\lambda_{INTER} > 0$; and

ii. Higher for the SRI for all SRI discount factors $0 < \beta \leq 1$.

iii. Higher for the stakeholder-oriented shareholder for all stakeholder discount factors $0 < \theta \leq 1$.

Proposition 13. *Assuming a common time discount factor, δ, all active owners that invest in adaptation invest identical amounts.*

Propositions 10 and 12 arises from the long-term common owner and SRI having the additional incentive related to damage to other agents in the model, and the long-term common owner also having the intra-industry incentive. Proposition 11 arises from the long-term common owner having the additional incentives related to the long-term and to damage to other agents in the model. Proposition 13 arises because adaptation is a private good benefiting only the firm. Thus if the incentive to address long-term damage to the firm is embedded in the objective and δ, the parameter driving the incentive, is identical across objectives, then all active owner types with the incentive to address long-term damage to the firm will invest identical amounts in adaptation.

D.2 Corporate governance process

Suppose there are two shareholders, $m = 1, 2$, of some firm, say firm i, and firm i's choices and outcomes are determined by management combining the recommendations of shareholders. Further suppose each shareholder's control over management and thus also the firm's final choice or outcome is represented by a control weight, $w_{i,m}$, where $\sum_m w_{i,m} = 1$, and shareholders provide their recommendations truthfully (so do not strategically choose what they recommend to management) and in accordance with a model where they are in full control. The firm's choices, c_i, and outcomes, o_i, are therefore given by:

$$c_i = \sum_m w_{i,m} c_{i,m} = c_{i,m} + w_{i,-m}(c_{i,-m} - c_{i,m}), \tag{170}$$

$$o_i = \sum_m w_{i,m} o_{i,m} = o_{i,m} + w_{i,-m}(o_{i,-m} - o_{i,m}), \tag{171}$$

where $c_{i,m}$ and $o_{i,m}$ are the choices and outcomes recommended by shareholder m. Therefore, the impact of increasing the control, as represented by the control weights, of shareholder $-m$ is:

$$\frac{\partial c_i}{\partial w_{i,-m}} = c_{i,-m} - c_{i,m}, \tag{172}$$

$$\frac{\partial o_i}{\partial w_{i,-m}} = o_{i,-m} - o_{i,m}. \tag{173}$$

Thus, if shareholder m is taken to be the short-term profit maximizer and shareholder $-m$ is taken to be an owner with any other active ownership objective, then the impact on firm-level choices and outcomes of increasing the control weight of the owner with the other active ownership objective is the difference between those choices and outcomes recommended by the owner with the other active ownership objective and those choices and outcomes recommended by the short-term profit maximizer.