01 Jan 2024

The Design of Emission Taxes in Markets with New Firm Acquisitions

Luis Gautier

Mahelet G. Fikru
Missouri University of Science and Technology, fikruma@mst.edu

Recommended Citation
Gautier, L., & Fikru, M. G. (2024). The Design of Emission Taxes in Markets with New Firm Acquisitions. *Environmental and Resource Economics* Springer.
The definitive version is available at https://doi.org/10.1007/s10640-024-00845-2

Environmental and Resource Economics
https://doi.org/10.1007/s10640-024-00845-2

The Design of Emission Taxes in Markets with New Firm Acquisitions

Luis Gautier[1,2] · **Mahelet G. Fikru**[3]

Accepted: 1 February 2024

Abstract

In the 1990s there was a great deal of interest in the study of the role of endogenous market structure under oligopoly in the characterization of emission taxes. This interest was instrumental in providing policy guidance on the design of emission taxes based on market characteristics. However, the literature has been silent on offering policy recommendations on the design of emission taxes under endogenous market structure in the presence of new firm acquisitions. We build a model where new firms enter the market where some are acquired by an incumbent multi-plant firm, altering the initial market structure. In this framework, we characterize the second-best emission tax and examine the role of the resulting market structure, in particular the role of acquiring more/fewer of the new firms, in the optimal design of emission tax. We argue that, under certain conditions, the acquisition of new firms may lead to higher taxation consistent with the Pigouvian rule or even exceed marginal damages. Our contribution is at the intersection of emission tax design and M &A (new firm acquisition) literature.

Keywords Emission tax · Pollution abatement · Start-ups · Free entry and exit · M&A

JEL Classification Q5 · G34

✉ Luis Gautier
lgautier@uttyler.edu; gautilui@uma.es

Mahelet G. Fikru
fikruma@mst.edu

[1] Department of Social Sciences, University of Texas at Tyler, 3900 University Blvd., Tyler, TX 75799, USA

[2] Departamento de Teoría e Historia Económica, Universidad de Málaga, El Ejido 6, 29013 Málaga, Spain

[3] Department of Economics, Missouri University of Science and Technology, 500 W 13th Street, Rolla, MO 65409, USA

Published online: 15 April 2024

1 Introduction

In the 1990s there was a great deal of interest in the study of the role of endogenous market structure under oligopoly in the characterization of emission taxes. This interest was instrumental in providing policy guidance on the design of emission taxes based on market characteristics. The works by Katsoulacos and Xepapadeas (1995), Lee (1999), Requate (1997) and Carraro et al. (1996), to name a few, are examples of this line of research. One of the key policy insights from this line of research is that the second-best emission tax can exceed marginal damages when the number of firms is endogenous. The reason for this result is that a higher emission tax controls excess entry while addressing damages from pollution.

Since the derivation of this insight, the literature has been silent on offering policy recommendations on the design of emission taxes under endogenous market structure *in the presence of new firm acquisitions*. What's the role of new firm acquisitions in the design of a second-best emission tax? Addressing this missing aspect from the literature is important for at least three reasons. First, new firm or startup acquisition is becoming a common strategy among firms regulated for environmental externalities. For instance, as sustainability continues to become a global priority, the renewable energy industry has experienced a significant number of startup acquisitions. Established power companies and investor owned utilities have acquired startups working on renewable energy technologies like solar, wind, or energy storage to expand their clean energy portfolios and meet environmental goals (e.g., multinational electric utility company, E.ON, acquired energy solutions startups such as Greenhouse and Lemonbeat). When incumbent firms acquire new firms for profit incentives, the market structure is altered which could in turn affect the second best emission tax. In this study, we examine the extent to which new firm acquisitions affect the design of emission taxes.

Second, an endogenous market structure *in the presence of new firm acquisitions* is important because managers no longer view firm acquisitions as a one-time combination of two or more otherwise independent firms (Kumar 2012). Rather they view such deals as part of their continuous restructuring strategy, where businesses come and go, in response to changing market, policy, and technical conditions. Market conditions change when new firms enter the market and compete with incumbent firms. Some new firms (e.g., start-ups) may be acquired by big corporate firms (Garcia et al. 2014) while others succeed to operate independently. With this in mind, we present a type of endogenous market structure that features entry of new firms (startups) followed by the acquisition of some/all by an incumbent firm and then study how such endogenous market structures affect the formulation of environmental policies. This framework differentiates our study from previous studies that have, thus far, focused on the impact of entry/exit conditions on optimal policy-making.

Third, our analysis contributes to the limited literature that models the relationship between environmental policies and mergers and acquisitions (M &A) as firm strategies (Zheng et al. 2021). On one hand, the M &A literature examines the extent to which such transactions alter market structures, and consequently firm behaviour in resource allocation (e.g., production and investment decisions). This resource allocation could in turn have measurable impacts on the natural environment. For instance, Lu (2021) shows that M &As motivated for the acquisition of greener technologies could help improve sustainability outcomes in environmentally regulated industries. On the other hand, the environmental policy literature studies the design of policy to tackle environmental challenges, with implications on the functioning of markets and firms' strategies. Economic factors are one of the key considerations for the design of optimal environmental policies where policy makers seek to balance costs (e.g., compliance cost, impact on prices, creating entry barriers, etc.) and benefits (e.g., environmental quality) (Xiao et al. 2021). We propose a framework for studying environmental policy design within an endogenous market structure where M &A parameters (i.e., the percent of new firms acquired) could influence optimal policy-making.

Several studies have characterized the design of emission taxes in oligopoly markets with a given firm strategy such as acquisitions when the number of firms is fixed (Fikru and Gautier 2017, 2020; Fikru and Lahiri 2013) or in the presence of free entry-exit absent firm acquisitions (e.g., Matsumura and Okumura 2014; Requate 2006). However, the literature has yet to examine the relationship between new firm acquisition strategies *and* the design of emission taxes in the presence of free entry-exit. Exploring such relationship is relevant because it offers policy guidance on the design of emission taxes based on industry characteristics, particularly where the acquisition of new firms is a key business strategy. Our model builds on the existing acquisition literature which uses Cournot markets (Salant et al. 1983; Farrell and Shapiro 1990; Blair and Haynes 2011; Nocke and Whinston 2013) and allows for free entry-exit (Werden and Froeb, 1998; Spector 2003; Cabral 2003; Davidson and Mukherjee 2007; Kao and Menezes 2010; Erkal and Piccinin 2010), by explicitly modeling new firm acquisitions by a multi-plant incumbent firm in the presence of an emission tax. This type of endogenous structure is new to the literature.

Overall, we argue that the acquisition of new firms in a post-acquisition market impacts the characterization of the emission tax. To illustrate we consider the entry of m new firms (e.g., start-ups) into a pollution-intensive industry regulated by an emission tax (t) where a percentage k of the new firms could be acquired by an incumbent multi-plant firm.

We show that the second-best emission tax is affected not only by the excess entry of new firms (m) as in Katsoulacos and Xepapadeas (1995), but also by the incentives for new firm acquisitions by an incumbent firm (k). Our results are in line with Katsoulacos and Xepapadeas' work because we show that the second-best emission tax may exceed marginal damages to control for excess entry. The additional insight gained from our model is that the acquisition of new firms may result in the emission tax exceeding marginal damages *further* because of the profits new firm acquisition generates. We show conditions under which the optimal emission tax in the given market structure (m new firms enter and k percent are acquired) is higher relative to the case where there is free entry but acquisitions are absent (i.e., as in Katsoulacos and Xepapadeas 1995). The driver for this result is the profits new firm acquisitions generate.

In Sect. 2 we present the model framework and present comparative statics results. In Sect. 3 we examine the role of new firm acquisitions on the characterization of the second-best emission tax. Section 4 concludes with policy implications.

2 The Model

We consider an industry where there is a fixed number of $N + 1$ plants owned by an incumbent multi-plant firm and M independent firms, where $N \geq 1$, $M \geq 2$. There is an endogenously determined number of new firms, m, which entry/exit the market (Davidson and Mukherjee 2007). A share k of these end up being bought by the incumbent multi-plant firm whereas a share $1 - k$ remain independent, where $\forall m \in \mathbb{N}$, $k \in (0, 1)$ s.t. $km \in \mathbb{N}$.

We allow for these m new firms to move across the incumbent versus independent firms group and thus the share k is endogenous. The incumbent firm, now a merged entity, owns $N+1+km$ plants (referred to as insiders) and there is a total of $M+(1-k)m$ independent firms referred to as outsiders.

There are two product varieties, one produced by insiders and the other by outsiders. Output levels for each insider and outsider are given by q and q^o, respectively. The inverse demand functions of the two product varieties produced by insiders and outsiders is given by $P=\alpha-\beta\sum q_j-\gamma\sum q_i^o$ and $P^o=\alpha^o-\beta^o\sum q_i^o-\gamma\sum q_j$, respectively, where $\beta>\gamma$, $\beta^o>\gamma$, $i=1,2,\ldots,M+(1-k)m$ and $j=1,2,\ldots,N+1+km$. γ indicates the degree of product differentiation, where $\gamma=0$ ($\gamma=\beta=\beta^o$) means the two products are completely different (homogeneous). Disutility from pollution or the social damage function is captured by $\varphi(E)$ where E is total emissions. The damage function is increasing and convex in E (Requate 2006).

Each insider's and outsider's cost function is given by $C_j(q_j,e_j)=(\sigma_j q_j-e_j)^2/2+c_j q_j+F_j$ and $C_i^o(q_i^o,e_i^o)=(\sigma_i^o q_i^o-e_i^o)^2/2+c_i^o q_i^o+F_i^o$ respectively, where σ and σ^o represent the pollution intensity of production and e and e^o represent the emission level (after abatement) of each insider and outsider respectively. Abatement refers to the amount of gross pollution cleaned up or removed to arrive at the final emission or release to the natural environment; and the cost function assumes abatement technology to be end-of-the-pipe type. We assume identical and constant marginal cost of production ($c=c^o$) and pollution intensities ($\sigma=\sigma^o$) across the two groups of firms. This assumption eliminates all production efficiency gains the merged entity may enjoy over the outsiders, which allows us to focus on the inflow-outflow of firms to and from the incumbent (k) when *all* plants owned by the merged entity are in operation. Each firm pays a per-unit tax t for each unit of emissions.

We consider a 4-stage game-theoretic model in a Cournot market as summarized in Fig. 1. In stage 1 a central regulator sets the emission tax via welfare maximization. In stage 2, m new firms enter the market where the free entry-exit of m new firms is characterized by the zero-profit condition, $\pi^o=0$ (Davidson and Mukherjee 2007). In stage 3, a share k of these m new firms (e.g., start-ups) is acquired by the incumbent multi-plant firm and the rest $1-k$ remain independent as part of the outsiders group. Specifically, a share k

Stages	Decision-maker	Decision	Objective
First	Government	Optimal emission tax	Maximize welfare
Second	New firms	Enter market	Zero outsider profit
Third	Incumbent multi-plant firm	Percent of new firms acquired	Reservation profits for insiders
Fourth	All firms	Production levels	Maximize profits

Fig. 1 Four stage game theocratic model

of new firms are acquired by the incumbent as long as each insider earns a positive profit, $\pi_j = \hat{\pi} > 0$ (reservation profits are positive); otherwise, they are not acquired and so remain part of the outsiders group. This characterization for the acquisitions of k percent of the new firms, using $\hat{\pi}$, ensures that all plants owned by the merged entity remain in operation. Production decision takes place in the last stage, stage 4 where all firms compete in a Cournot–Nash fashion by choosing the level of emissions and output. The model is solved via backward induction where firms make production decisions in the post-acquisition market assuming preceding steps have occurred, followed by moving backwards through the stages until reaching the initial stage of the game, where the optimal emission tax is determined. The contribution of this model set-up to the extant literature that examines emission tax design in endogenous market structures is the addition of stage 3 which opens the door for the possibility of some/all of the new firm entrants to be acquired by an incumbent firm, hence altering the market structure which has bearings for the characterization of optimal policy.

In this setup $\hat{\pi}$ is a constant. If $\hat{\pi} = 0$, then $k = 0$ because each insider is not generating positive profits for the incumbent. The higher the positive level of profits, $\hat{\pi}$, the higher the share of new firms acquired by the incumbent. With $\hat{\pi} > 0$ the incumbent has incentives to acquire some but not all of the new firms. That is, we assume $\hat{\pi} > 0$ is not large enough to allow for $k = 1$. Instead of explaining what leads up to the acquisition, which is addressed in previous studies (e.g., Qiu and Zhou 2006), we assume $\hat{\pi}$ to be exogenous. The acquisition of new firms is assumed to be costless, which allows us to focus on the role of k on optimal taxation.

2.1 Equilibrium

We first characterize the equilibrium production decision (stage 4). Post-acquisition the incumbent firm maximizes joint profits which is the sum of insider profits given by $\Pi = \sum \pi_j = \sum P_j q_j - \sum C_j - t \sum e_j$ where $j = 1, 2, \ldots, N + 1 + km$. The first-order conditions of the profit maximization problem under symmetry are given by

$$P - c - \beta q(N + 1 + km) - \sigma(\sigma q - e) = 0 \tag{1}$$

$$\sigma q - e - t = 0 \tag{2}$$

where $q_1 = q_2 \ldots, q_{N+1+km} = q$, $e_1 = e_2 \ldots, e_{N+1+km} = e$, and $P_1 = P_2 = \ldots = P$.

Each outsider maximizes individual profits $\pi_i^o = P_i^o q_i^o - C_i^o - te_i^o$ where $i = 1, 2, \ldots, M + (1 - k)m$. Under symmetry, first-order conditions for the profit maximization problem of each outsider are:

$$P^o - c - \beta^o q^o - \sigma^o(\sigma^o q^o - e^o) = 0 \tag{3}$$

$$\sigma^o q^o - e^o - t = 0 \tag{4}$$

where $q_1^o = q_2^o \ldots, q_{M+(1-k)m}^o = q^o$, $e_1^o = e_2^o \ldots, e_{M+(1-k)m}^o = e^o$, and $P_1^o = P_2^o = \cdots = P^o$.

Under symmetry the inverse demand functions are $P = \alpha - \beta q(N + 1 + km) - \gamma q^o(M + (1 - k)m)$ and $P^o = \alpha - \beta^o q^o(M + (1 - k)m) - \gamma q(N + 1 + km)$. When the market clears we have $D^o = q^o(M + (1 - k)m)$ and $D = q(N + 1 + km)$ where D^o and D represent aggregate output sold from the outsiders' and insiders' brand respectively.

In stage 3, profit of insiders changes with k until $\pi = \hat{\pi}$ is achieved at equilibrium where as in stage 2 the profit of outsiders goes to zero to determine the equilibrium level of firm firm entry at equilibrium. Thus, the equilibrium vector q, e, q^o, e^o, k, m, is determined by (1)–(4), $\pi = \hat{\pi}$, $\pi^o = 0$ and the two inverse demand functions. First, from Eqs. (1)–(4) we obtain $q^o(k, m, t)$, $q(k, m, t)$ as the fourth stage solution. Second, from equation $\pi = \hat{\pi}$ and using $q^o(k, m, t)$, $q(k, m, t)$, we characterize $k(m, t)$ as the third stage solution. Third, from equation $\pi^o = 0$ along with $q^o(k, m, t)$, $q(k, m, t)$, $k(m, t)$ we characterize $m(t)$ as the second stage solution. Finally, substituting $m(t)$ back into $k(m, t)$ yields $k(t)$; and substituting $m(t)$ and $k(t)$ into $q^o(k, m, t)$,$q(k, m, t)$ characterizes the equilibrium level of output of each insider and outsider firm.

Closed-form solutions are complex and non-linear and so we rely on comparative statics to discuss how an exogenous change in the emission tax affects the equilibrium values of output, emissions, number of new firm entry, and percent of new firms acquired. This intermediate step in the analysis helps reduce model complexities, compare results to existing literature, and draw policy implications. We assume interior solutions throughout.

2.2 Comparative Statics

In this sub-section, we use comparative statics to examine the impact of the tax in affecting equilibrium values of production (q, q^o), entry-exit of new firms (m), and percent of new firms acquired (k). We present the complete comparative statics exercise in Appendix A. Differentiation of (1)–(4), $\pi = \hat{\pi}$, $\pi^o = 0$, the two inverse demand functions and the market clearing conditions gives four equations in four unknowns, dD^o, dD, dm, dk. Consistent with the literature (e.g., Requate 2006), we consider the case where output and emissions fall with an increase in the emission tax and the presence of k does not qualitatively affect the impact of t on D and D^o, where $\partial D/\partial t < 0$, $\partial D^o/\partial t < 0$. It is noteworthy that the end-of-pipe abatement cost structure does not play a pivotal role in the comparative statics results on output. The qualitative results from the comparative statics do not change in the presence of a more general cost function (see Appendix A). Consistent with Requate (2006) and Lee (1999) we find that, if abatement effects are negligible, $\partial m/\partial t < 0$ holds. *This in turn generates economic rent for each firm (insiders and outsiders) due to fewer new firms joining the industry.*

The reason why $\partial m/\partial t < 0$ holds with small abatement effects is that as emission tax increases, the cost of production also increases and this additional cost discourages new firms from considering entry into the market. For example, higher compliance costs can create a barrier to entry. Moreover, this effect could be magnified in an oligopolistic market, where the tax burden is better absorbed by established firms potentially limiting the competitive advantage for new entrants. However, if abatement effects were high, the tax induces all firms to invest more in abatement to reduce their emissions and minimize their tax burden. This could create opportunities for new firms as they may be able to enter the market with a competitive advantage thus leading to $\partial m/\partial t > 0$. Large abatement effects imply that tax-savings are significant and thus firms can strategically use abatement to increase their profits by avoiding tax payments. In this study, we assume that abatement effects are of a smaller magnitude so as to focus on the former (tax burden) effect which is consistent with most real world experiences. In addition, this assumption is in line with the existing literature and allows us to compare our results to previous findings (Requate 2006; Lee 1999). A small abatement effect allows us to focus on the case where output falls with emission tax. We refer readers to Appendix C for a general case where abatement effects are not small.

Assumption 2.1 Abatement effects from the emission tax are small.

With this in mind, the change in k due to the tax is given by $\rho m dk = [(2\beta\sigma^o - \gamma\sigma)(kq - (1-k)q^o) + t\eta_k]dt$, where abatement effects, represented by the second term ($t\eta_k$), are assumed to be small from Assumption 2.1. $\rho = 2\beta\beta^o - \gamma^2 > 0$ and $\eta_k > 0$ is a complex expression which captures the abatement effect of the tax (see Appendix A). Thus the net effect is that a tax increase reduces k *if and only if* $kq - (1-k)q^o < 0 \Leftrightarrow k < q^o/(q + q^o)$. That is, if the market share of each outsider's output is sufficiently large, then the incentive to remain as an outsider is high which leads to a reduction in k. More generally, there will be fewer (more) new firm acquisitions with a tax increase, if the output share of outsiders is higher (lower), i.e., if $k < (>) q^o/(q + q^o)$ then $\partial k/\partial t < (>)0$. This means there is a threshold output share, $\bar{k}$, which characterizes the extent to which more new firms are acquired when the tax increases.

The M &A literature shows that due to oligopoly interaction, outsiders will respond to a given acquisition by increasing production levels making the merger less profitable (Gelves 2014; Fikru and Gautier 2020). In this context, we argue that if the market share of outsiders is relatively high, this discourages acquisitions with an increase in the emission tax because when outsiders have a high enough production share, their strategic response to the acquisition (increase output) is amplified rendering the acquisition less profitable. That is, with large enough production share, outsiders are able to respond to the acquisition, thereby making the deal less attractive for the incumbent firm. On the contrary, when the market share of outsiders is relatively small, their strategic response to the acquisition (by increasing output) is small thus inducing more new firms to be bought off. In this case the response of the outsiders is not strong enough to make the acquisition less attractive. This result is summarized as follows which serves as an intermediate tool to fully characterize the impact of acquisitions on optimal policy making.

Lemma 2.2 *There is a threshold share of output of outsiders,* $\bar{k} = q^0/(q + q^0)$, *which satisfies* (i) $\partial k/\partial t = 0$ *at* $k = \bar{k}$ *and* (ii) $\partial k/\partial t > (<)0$, *if and only if* $k > (<)\bar{k}$.

While a higher tax controls for the entry of new firms ($\partial m/\partial t < 0$), at the same time it could lead to a larger or smaller share of new firms being acquired ($\partial k/\partial t > 0$ or $\partial k/\partial t < 0$) depending on the size of the output share of each outsider. That is, an increase in the emission tax can either increase or decrease the incentive to acquire new firms and facilitates, for example, the 'from start-up to bought up' strategy, even when entry of new firms into the market is restricted by the tax.

Lemma 2.2 suggests that an emission tax could affect the extent to which new firms end up being part of a multi-plant incumbent (i.e., acquired) or remain independent. This is generally consistent with theoretical and empirical studies which show that firm acquisitions may be driven by the presence of environmental policy (Creti and Sanin 2017; PricewaterhouseCoopers 2012; Gomes and Marsat 2018; Kwon et al. 2018). For example, Creti and Sanin (2017) argue that acquisition deals in the energy industry could be triggered by uncertainty about tightening environmental regulation. Another empirical study by Jacqz (2020) shows that firms improve their environmental performance (reduce toxic chemical releases) after engaging in M &A deals. While these studies are specific to M &A deals between two or more incumbent firms, our findings are specific to the acquisition of new firms by incumbent firms.

Overall, the comparative static results suggest that in certain industries a higher tax rate could discourage start-ups leading to only fewer firms entering the market (compared to the case where tax is lower). At the same time the higher tax could affect the (now fewer) start-ups' ownership as being the incumbent firm versus remain independent. While previous studies have examined the effect of emission tax on market structure, this particular channel (i.e. $\partial k/\partial t$) is new to the literature.

3 Welfare Maximization and Optimal Emission Tax

The central regulator sets the emission tax by maximizing social welfare in stage 1 (Yu 2020). The emission tax deals with the negative externality caused by pollution, the oligopolistic market structure, entry of new firms, and the increase in the incumbent's market power when new firms are acquired. The last effect makes the role of the tax unique from previous studies.

Welfare is defined as the sum of consumer surplus, profit of insiders, tax revenue collected by the government, and total damages from emissions in the industry where $\sum e_j + \sum e_i^o = E$. The damage function fulfils the properties $\varphi' > 0$ and $\varphi'' > 0$. Outsider profits do not show on the welfare function because free entry-exit is captured by the zero-profit condition:

$$W = CS\Big(\sum q_j + \sum q_i^o\Big) + \sum \pi_j + t\Big(\sum e_j + \sum e_i^o\Big) - \varphi\Big(\sum e_j + \sum e_i^o\Big) \tag{5}$$

Maximization of Eq. (5) with respect to the tax, t, gives $\partial W/\partial t = 0$ and hence

$$\begin{aligned} t^* &= \varphi' - \frac{\left(-D\frac{\partial P}{\partial t} - D^o\frac{\partial P^o}{\partial t} + E\right)}{\partial E/\partial t} - \frac{1}{\partial E/\partial t}(N+1+km)\frac{\partial \pi}{\partial t} \\ &\quad - \frac{\pi}{\partial E/\partial t}\left(k\frac{\partial m}{\partial t} + m\frac{\partial k}{\partial t}\right) \\ &= \varphi' - \frac{\left(-D^o\frac{\partial P^o}{\partial t} + (M + (1-k)me^o)\right)}{\partial E/\partial t} - \frac{1}{\partial E/\partial t}(N+1+km)^2\beta q\frac{\partial q}{\partial t} \\ &\quad - \frac{\pi}{\partial E/\partial t}\left(k\frac{\partial m}{\partial t} + m\frac{\partial k}{\partial t}\right) \end{aligned} \tag{6}$$

where $\partial E/\partial t < 0$ (see Appendix A). The first term in Eq. (6) denotes damage from emissions and the second term output distortion effects. The third term captures reductions in the tax to offset anti-competitive effects from the acquisitions by raising insiders output. The fourth term reduces the tax to attract more new firms into the market, which for given k raises the market power of the incumbent, thereby raising profits.

The fifth effect says the optimal emission tax should be (1) increased if $\partial k/\partial t > 0$ because this encourages more new firms to be acquired by the incumbent thereby raising profits, or (2) decreased if $\partial k/\partial t < 0$ because this discourages acquisitions. While Requate (1997, 2006), Katsoulacos and Xepapadeas (1995) and Lee (1999) examine the effect of free entry/exit on optimal taxation, we capture the additional role of new firm acquisitions (k).

3.1 Impact of Acquisitions on the Second-Best Emission Tax

To analyze the role of k in the characterization of the second-best emission tax we evaluate $\partial W/\partial t = 0$ at $\hat{\pi}$. This is because the extent of the acquisition of new firms, k, depends crucially on $\hat{\pi}$. Figure 2 illustrates the results. We consider the Pigouvian rule, t_p, as a reference point, followed by the case of emission tax under oligopoly with free entry-exit, t_o, and in the presence of a multi-plant incumbent, t_m. These reference points are initially considered absent any acquisition of new firms where $\hat{\pi} = 0$ so that $k = 0$, and the incentive to acquire new firms vanishes.

Figure 2 is divided into two broad areas, namely, above (below) t_m where k puts an upward (downward) pressure on the emission tax. If the outsider's output share is relatively large, then $\partial k/\partial t < 0$ which consequently puts a downward pressure on the tax. In this case lower taxation induces acquisition of a higher share of new firms thereby raising profits, while addressing anti-competitive effects from the acquisition and output distortion effects. But if outsider's output share is relatively small, then the emission tax is pushed upwards as long as the increase in new firm acquisitions and resulting increase in profits is large enough. This result raises the possibility of obtaining the Pigouvian rule or even exceed it as long as the gains from the profits generated through the acquisitions of new firms by the incumbent are large enough. We also point to the shaded area in Fig. 2 where $\partial k/\partial t = 0$, meaning that the tax is decreased in order to address anti-competitive effects from the acquisition and output distortion effects, while raising profits of insiders. In this case the share of outsider's output is such that the tax does not impact welfare via the share of new firms acquired.

Proposition 3.1 *The optimal emission tax exceeds marginal damages, if the incentives to increase the acquisition of new firms by the incumbent are sufficiently large.*

We explore the implications of Proposition 3.1 by looking at cases where taxation can increase the acquisition of new firms. In particular, if $t^* > \varphi'$, then Eq. (6) gives

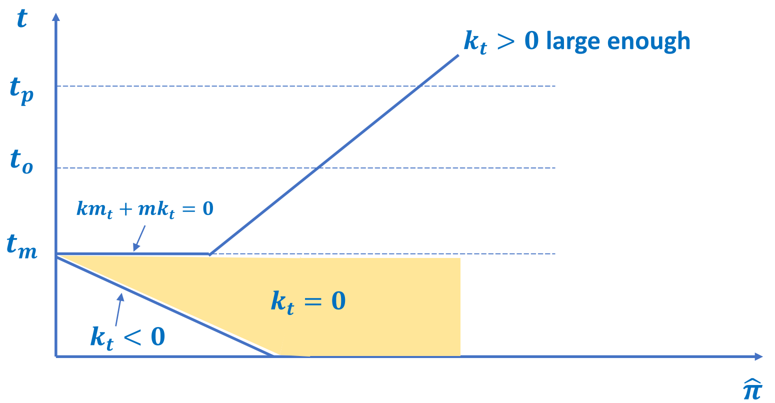

Fig. 2 Second-best emission tax and new firm acquisition, $k_t \equiv \partial k/\partial t$

$$\partial k/\partial t > \frac{D\frac{\partial P}{\partial t} + D^o\frac{\partial P^o}{\partial t} - E - \pi k\frac{\partial m}{\partial t} - (N+1+km)\frac{\partial \pi}{\partial t}}{\pi m} \tag{7}$$

From Eq. (7) we point to two possible cases where higher taxation can induce the acquisition of new firms; that is, the left-hand-side of the inequality is larger. First, when prices are sensitive to the emission tax (that is, $\partial P/\partial t$ and/or $\partial P^o/\partial t$ are large), a tax increase leads to a large increase in prices and, as a result, the tax is more effective ($\partial k/\partial t > 0$ and large) to induce the acquisition for welfare enhancement. This is because with sensitive prices to tax, economic rents increase via a tax increase. Second, when the emission tax deters entry to a large extent ($\partial m/\partial t$ is more negative) there are fewer firms in the market and, therefore, the regulator can use the tax to induce the acquisition of new firms by the incumbent for welfare enhancement. This is because of the economic rents generated via entry restrictions.

Proposition 3.2 *Let $t^* > \varphi'$. Then, if (i) prices are highly sensitive to tax or (ii) the emission tax deters entry of new firms to a large extent, then the emission tax can induce new firm acquisitions for welfare enhancement.*

3.2 Discussion and Comparison with Previous Studies

We now explore comparisons with the existing literature. To do this, we assume linear damages so that marginal damages equal one. In Fig. 3, the dashed lines replicate the result in Katsoulacos and Xepapadeas (1995), where they show the existence of a tax, $\bar{t}$, which equates the second-best optimal number of firms (characterized by $W_m(m,t) = 0$) and the equilibrium free-entry number of firms (characterized by $\pi^o(m,t) = 0$). They argue that the second-best emission tax lies between marginal damages and $\bar{t}$ to control for excess entry. The reason for controlling for excess entry is because the oligopolistic market structure

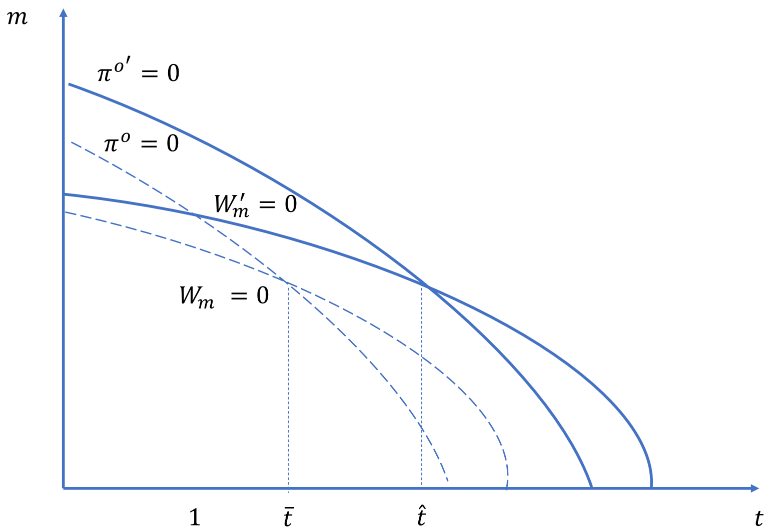

Fig. 3 Second-best emission tax and number of new firms

generates potential rents, which translates into an excessive number of firms entering the market (Requate 2006, p. 160). This issue of excess entry is well-established in the literature. In Fig. 3 we derive an analogous set of curves (shown with solid lines) in the presence of acquisitions. See Appendix B for a derivation. The functions $W'_m(m, t, k) = 0$ and $\pi^{o'}(m, t, k) = 0$ (resp., $W_m(m, t) = 0$ and $\pi^o(m, t) = 0$) characterize the second-best optimal number of firms and the free-entry equilibrium number of firms in the presence of (resp., absence) acquisition of new firms.

We point to the case where the presence of acquisitions induces entry of new firms. That is, because acquisitions generate enough additional profits there are incentives for new firms to enter the market. In the context of Fig. 3, this implies that for any tax the number of firms associated with $W'_m = 0$ ($\pi^{o'} = 0$) is higher than the number of firms associated with $W_m = 0$ ($\pi^o = 0$). This in turn means that the tax that equates the second-best optimal number of firms to the equilibrium free-entry one, $\hat{t}$, is higher in the presence of acquisitions i.e., $\hat{t} > \bar{t}$. Intuitively, although the tax controls entry, it also induces the acquisitions of new firms. But at the same time the acquisition of new firms generates higher industry profits and thus the entry of new firms. However, it is not clear whether the number of firms produced by the emission tax in the presence/absence of acquisitions is relatively larger/smaller.

Further, the second-best emission tax in the presence of acquisitions, t^*, defined in Proposition 3.2 may lie anywhere between marginal damages (equal to one in the context of Fig. 3) and $\hat{t}$ depending on the incentive for acquisitions created by the tax. Intuitively, the incentive for acquisitions, $\partial k/\partial t$, has to be large enough so that taxation exceeds marginal damages, but at the same time the incentives for acquisitions can't be too high. As a result, the incentive for acquisitions, $\partial k/\partial t$, is bounded. This is because if the incentive for new firm acquisitions is not bounded, then there is no tax, $\hat{t}$, which equates the second-best optimal number of firms to the free-entry equilibrium number of firms.

Proposition 3.3 *In the presence of new firm acquisition the emission tax that equates the second-best optimal number of firms to the free-entry equilibrium number of firms*, $\hat{t}$, *exceeds that absent new firm acquisitions*, $\bar{t}$.

Proposition 3.4 *The second-best emission tax in the presence of acquisitions*, t^*, *lies between marginal damages and* $\hat{t}$, *if the incentive for new firm acquisition arising from the tax is bounded.*

Proof See Appendix B. □

4 Conclusion and Policy Implications

We examine the inter-play between emission tax designs and firm strategy with respect to acquiring new firms. We study the extent an emission tax induces the acquisition of new firms by the incumbent and find that an increase in the emission tax may facilitate the acquisition of a higher/lower share of new firms depending on the size of the output share of outsiders. Consequently, the presence of new firm acquisitions may lead to higher taxation which can exceed marginal damages and taxation absent new firm acquisitions strategy.

Our results have two main policy implications in industries regulated for their emissions. First, the literature has already established that environmental policies such as an emission tax ought to be designed by taking into consideration specific market structure characteristics. For example, Katsoulacos and Xepapadeas (1995) point to two important market characteristics to consider in environmental policy design: the type of oligopoly competition among firms and entry of new firms. Our results indicate that in addition to these market structure characteristics, environmental policy-makers ought to consider firm strategies with respect to acquisition decisions. In particular, we argue that in industries where new firm acquisitions are common, unregulated and profitable (e.g., technology industry, food processing industry) the second-best emission tax rate (e.g. dollar per unit of emissions) is likely to be higher compared to the tax rate in industries where new firm acquisitions are less common or more regulated by anti-trust policies. Thus, the design of optimal emission taxation ought to consider not just potential entry or new firms or lack of, but also what happens to the ownership status of those firms that enter a market.

Further, Katsoulacos and Xepapadeas (1995) show that in oligopoly markets with free entry and exit the characterization of the second-best emission tax depends not just on the extent of marginal pollution damages, but also considers output distortions and restricting entry from what is socially optimal. Our model offers additional insight for this characterization, particularly in the presence incentives of the incumbent firms to acquire a share of new firms that enter the market. Identifying these incentives is important because it allows to design a second-best emission tax to restrict entry close enough to the second-best optimum.

Second, our model illustrates how environmental policy and the emission tax rate could directly affect the decision of incumbent firms to acquire new firms. This implies that prospective buyers in markets where pollution is regulated could benefit from comprehensively understanding the potential impact of changes in environmental policy on their acquisition decisions. In turn, policy-makers ought to be aware of how firms plan to respond to anticipated policy changes and whether such strategic responses could reduce environmental damages.

The modeling approach is not without limitations. While several studies have examined why acquisitions take place endogenously (e.g., Fikru and Gautier 2016), we focus on the case where the acquisition is assumed to occur exogenously.

As it stands, an incumbent firm acquires a startup if “reservation profits” are positive, where reservation profits are exogenous. The profitability of acquisitions, however, is in the real-world an endogenous outcome, which could potentially be shaped by emission taxes. This has not been captured by the model presented in this study. Future studies can extend the given model by comparing profits pre- and post-merger and deriving conditions underlying a profitable number of startups are acquired.

Appendices

Appendix A: Comparative Statics

We first characterize the equilibrium via backward induction. First, from Eqs. (1)–(4) we obtain $q^o(k,m,t)$, $q(k, m, t)$. Second, from equation $\pi = \hat{\pi}$ and using $q^o(k,m,t)$, $q(k, m, t)$, we characterize $k(m, t)$. Third, from equation $\pi^o = 0$ along with $q^o(k,m,t)$, $q(k, m, t)$, $k(m, t)$ we characterize $m(t)$. Finally, substituting $m(t)$ back into $k(m, t)$ yields $k(t)$; and substituting $m(t)$ and $k(t)$ into $q^o(k, m, t)$, $q(k, m, t)$ characterizes the equilibrium level of number of new firms, share of new firm acquisition and output of each insider and outsider.

With this equilibrium in mind, differentiation of (1)–(4), $\pi = \hat{\pi}$, $\pi^o = 0$, the two inverse demand functions under symmetry ($P = \alpha - \beta q(N + 1 + km) - \gamma q^o(M + m(1 - k))$ and $P^o = \alpha - \beta q^o(M + m(1 - k)) - \gamma q(N + 1 + km)$) and using the market clearing conditions, $D = q(N + 1 + km)$ and $D^o = q^o(M + (m(1 - k))$, gives four equations in four unknowns, dD^o, dD, dm, dk:

$$-\beta^o(\mu + 1)dD^o - \gamma\mu dD + \beta^o q^o(1 - k)dm - \beta^o q^o mdk = \mu\sigma^o dt \tag{A.1}$$

$$-\gamma dD^o - 2\beta dD = \sigma dt \tag{A.2}$$

$$\beta^o q^o(1 - \mu)dD^o - q^o\gamma\mu dD - \beta^o(q^o)^2(1 - k)dm + \beta^o(q^o)^2 mdk = e^o\mu dt \tag{A.3}$$

$$-\gamma q dD^o - \beta q^2 kdm - \beta q^2 mdk = edt + d\hat{\pi} \tag{A.4}$$

where $\mu = M + (1 - k)m$ represents the total number of outsiders.

Next, we offer a detailed derivation of (A.1)–(A.4). But first, consider $D = q(N + 1 + km)$ and $D^o = q^o(M + (m(1 - k))$. Hence,

$$dD^o = \mu dq^o + q^o(1 - k)dm - q^o mdk \tag{A.5}$$

$$dD = qkdm + qmdk + (N + 1 + km)dq \tag{A.6}$$

Hence,

$$\mu dq^o = dD^o - q^o(1 - k)dm + q^o mdk \tag{A.7}$$

$$(N + 1 + km)dq = -qkdm - qmdk + (N + 1 + km)dD \tag{A.8}$$

Next, to derive (A.1) combine (1) and (2), and impose $D = q(N + 1 + km)$ and $D^o = q^o(M + (m(1 - k))$. This gives $\alpha - \beta q^o - \beta D^o - \gamma D - \sigma^o t = 0$. Differentiation gives

$$-\beta dq^o - \beta dD^o - \gamma dD - \sigma^o dt = 0 \tag{A.9}$$

where substituting (A.7) into (A.9) and collecting terms gives Eq. (A.1).

Next, to derive (A.2) combine (3) and (4), and impose $D = q(N + 1 + km)$ and $D^o = q^o(M + (m(1 - k))$. This gives $\alpha - 2\beta D - \gamma D^o - \sigma t = 0$. Differentiation gives

$$-2\beta dD - \gamma dD^o - \sigma dt = 0 \tag{A.10}$$

This is (A.2).

Next, to derive (A.4) consider $\hat{\pi} = \pi$, where $\pi_j = \pi$, $\forall j$. Impose $D = q(N + 1 + km)$ and $D^o = q^o(M + (m(1 - k))$ into profits π. Simplifying profits gives $\hat{\pi} = (\alpha - \beta D - \gamma D^o - \sigma t)q + t^2/2 - F$. Differentiation gives

$$d\hat{\pi} = (-\beta dD - \gamma dD^o - \sigma dt)q + (\alpha - \beta D - \gamma D^o - \sigma t)dq + tdt \tag{A.11}$$

where (i) imposing first-order-condition $\beta q(N + 1 + km) = \alpha - \beta D - \gamma D^o - \sigma t$, where $\beta q(N + 1 + km) = \beta D$; (ii) simplifying $-\sigma dt + tdt$ using $e = \sigma q - t$; and (iii) substituting (A.8) gives

$$d\hat{\pi} = -\gamma q dD^o - \beta q^2 k dm - \beta q^2 m dk - e dt \tag{A.12}$$

This is Eq. (A.4).

Next, to derive (A.3) consider $\pi^o = 0$. Impose $D = q(N + 1 + km)$ and $D^o = q^o(M + (m(1-k))$ into profits π^o. Simplifying profits gives $\pi^o = (P^o - c - \sigma^o t)q^o + t^2/2 - F$. Differentiation and imposing first-order condition $\beta^o q^o$ gives

$$(-\beta^o dD^o - \gamma dD)q^o + (\beta^o q^o)dq^o - e^o dt = 0 \tag{A.13}$$

where substituting (A.7) and simplifying gives (A.3).

We assume $d\hat{\pi}$ is zero; that is, each insider's reservation profit is small relative to the market and thus $\hat{\pi}$ constant. Using (A.1)–(A.4) yields $\rho dD^o = [t\beta/q^o - (2\beta\sigma^o - \gamma\sigma)]dt < 0$, $\rho dD = [t\gamma/2q^o - (\beta^o\sigma - \gamma\sigma^o)]dt < 0$. In addition, $\rho dm = \left[\left(\frac{-2(\beta^o\sigma - \gamma\sigma^o)}{q} - \frac{(2\beta\sigma^o - \gamma\sigma)}{q^o}\right) + t\eta_m\right]dt$, $\rho mdk = \left[(2\beta\sigma^o - \gamma\sigma)(qk - (1-k)q^o) + t\eta_k\right]dt$ where $\rho = 2\beta\beta^o - \gamma^2 > 0$, $\eta_m > 0$ and $\eta_k > 0$ are complicated expressions, which denote the abatement effect; for example, $\eta_k = 2\beta\beta^o\left(2\beta^o q^{o^2}(1-k) - (\mu+1)\beta q^2 k\right) - \gamma^2\left(2\beta^o q^{o^2}(1-k) - \beta q^2 k\right)$.

The effect of the tax on total emissions is given by $\frac{\partial E}{\partial t} = \sigma\frac{\partial D}{\partial t} + \sigma^o\frac{\partial D^o}{\partial t} - (N + 1 + km) - (M + (1-k)m) - t\frac{\partial m}{\partial t} < 0$ by Assumption 2.1 (i.e., the last term is small).

We now turn to the comparative statics exercise for the case where the cost function is general. Consider a cost function $C(q, e)$, which satisfies (subscripts denote partial derivatives) $C_q > 0$, $C_{qq} > 0$, $-C_e > 0$, $C_{ee} > 0$, $-C_{eq} = -C_{qe} > 0$, $C_{qq}C_{ee} - C_{qe}C_{eq} \geq 0$. These are standard properties of the cost function with abatement (see Requate 2006, p. 126). Similar to the comparative statics exercise explained earlier (but now with a more general cost function) we obtain the following system of equations:

$$\begin{aligned}
-(\beta^o(\mu+1) + \lambda)dD^o - \gamma\mu dD + q^o(1-k)(\beta^o + \lambda)dm - q^o m(\beta^o + \lambda)dk &= \mu\sigma^o dt \\
-\gamma dD^o - \left(2\beta + \frac{\lambda}{N+1+km}\right)dD + qk\frac{\lambda}{N+1+km}dm + qm\frac{\lambda}{N+1+km}dk &= \sigma dt \\
\beta^o q^o(1-\mu)dD^o - q^o\gamma\mu dD - \beta^o(q^o)^2(1-k)dm + \beta^o(q^o)^2 m dk &= e^o\mu dt \\
-\gamma q dD^o - \beta q^2 k dm - \beta q^2 m dk &= e dt + d\hat{\pi}
\end{aligned}$$

where $\lambda = (C_{ee}C_{qq} - C_{eq}C_{qe})/C_{ee}$, $\sigma = -C_{eq}/C_{ee}$, $\lambda^o = (C^o_{e^oe^o}C^o_{q^oq^o} - C^o_{e^oq^o}C^o_{q^oe^o})/C^o_{e^oe^o}$, $\sigma^o = -C^o_{e^oq^o}/C^o_{e^oe^o}$. It is noteworthy that (i) in the case of end-of-pipe $\lambda = 0$ in which case we obtain Eqs. (A.1) and (A.2), and (ii) the last two equations in the system are identical to (A.3) and (A.4) so the presence of a general cost function does not play any role. To illustrate the role of the general cost function in the comparative statics we show the expression for dD^o:

$$\frac{H}{\mu 2\beta^o \beta q^{o^2} q^2 m} \frac{dD^o}{dt} = -(2\beta\sigma^o - \gamma\sigma) + \beta t/q^o + \frac{1}{2\beta^o}\big(-\lambda^o(2\beta\sigma^o - \gamma\sigma + 2\beta t/q^o) + \lambda(-2\beta\sigma^o + t\beta^o/q^o) - e^o\lambda\lambda^o/q^o\big) - \frac{e\gamma\lambda\lambda^o}{2\beta^o\beta q^o q} \tag{A.14}$$

where $H > 0$ is the determinant of the coefficient matrix and $\mu = M + (1-k)m$ is defined as before. The first line in (A.14) is the same as in the case of an end-of-pipe cost function, which we consider to be negative to capture the standard case where the tax lowers output i.e., small abatement effect, $t\beta/q^o$. And the second and third lines capture the role of the general cost function, where the second and third lines are negative. The second and third lines vanish in the case of an end-of-pipe cost function since $\lambda = 0$, $\lambda^o = 0$. As a result, the presence of a general cost function does not change the qualitative results of dD^o/dt. An analogous expression is obtained for dD/dt.

Appendix B: Derivation of Fig. 3

We first argue the condition under which $\partial m/\partial k > 0$. This is the case we consider in Fig. 3 i.e., acquisitions generate profits so that more firms enter the market. This happens if $\pi_k^{o'} + \pi_k > 0$. In other words, acquisitions of firms by the incumbent offsets any profits loss of the outsiders which induces more firms into the market. Formally, differentiation of $\pi(m,k) + \pi^{o'}(m,k) = 0$ gives $dm/dk = -(\pi_k^{o'} + \pi_k)/(\pi_m^{o'} + \pi_m) > 0$, where the denominator is negative.

Part (i)—Intersection point of solid lines at $\hat{t}$ in Fig. 3 requires $\partial k/\partial t$ to be bounded. That is, the effect of the tax on the acquisition of new firms can't be too large. This is because with too large an effect the emission tax at the intersection point in the figure would not be possible since the number of firms determined via the zero-profit condition would be too large (too many firms would be attracted by $\partial k/\partial t$) relative to the second-best optimal one. First, we show that $\partial k/\partial t < \eta_1$, where η_1 is defined below. (a) Consider $\pi^{o'}(m,t,k)$, whence $-dm/dt = (\pi_t^{o'}/\pi_m^{o'}) + (\pi_k^{o'}/\pi_m^{o'})k_t$, where $k_t = \partial k/\partial t$. (b) Consider $W'_m(m,t,m(k))$, whence $-dm/dt = (W'_{mt}/W'_{mm}) + (m_k)k_t$. Then, intersection point in Fig. 3 requires the absolute value of dm/dt from (a) to exceed that from (b). That is,

$$\partial k/\partial t < \frac{(\pi_t^{o'}/\pi_m^{o'}) - (W'_{mt}/W'_{mm})}{m_k - (\pi_k^{o'}/\pi_m^{o'})} = \eta_1 \tag{B.1}$$

Part (ii)—The welfare-maximizing tax in the presence of acquisitions, t^*, lies between one (i.e., marginal damages, which is equal to one in the case of Fig. 3) and the tax that equates the welfare-maximizing number of firms and the free-entry number of firms, $\hat{t}$. The condition which ensures $t^* > 1$ is given by (7) where $\varphi' = 1$ and we label the RHS as η_2. Hence, $1 < t^* < \hat{t}$, if $\eta_2 < \partial k/\partial t < \eta_1$; that is, $\partial k/\partial t$ is large but not too large i.e., $\partial k/\partial t$ is bounded.

Appendix C: Illustration of the Condition in Lemma 2.2 and the Case Where Abatement Effects are Large

Consider parameter values i.e., $\alpha = 1$, $c = 0$, $\beta = \beta^o = \gamma = 1$, $M = 4$, $N = 1$, $\hat{\pi} = 1/12$, $F = 1/1000$. We use Mathematica to solve the model via backward induction (as explained at the beginning of Appendix A) and illustrate the condition in Lemma 2.2. For given range of the emission tax, m is a decreasing function of the emission tax (which is the case we focus on the paper, where abatement effects are small), while k can be an increasing or decreasing function of the emission tax for this same range. Using the solution of the model we derive the share $q^o/(q + q^o)$ as a function of the emission tax, which we find to be approximately 30%. This is our threshold output share referred to in the paper. With these in mind and using the condition $k > q^o/(q + q^o)$ in Lemma 2.2, our results indicate that for given range of the emission tax, k increases with the emission tax and so $k > q^o/(q + q^o) = 30\%$. But k decreases with the emission tax and so $k < q^o/(q + q^o) = 30\%$. See the Figure below.

Figure 4 shows that for $t \in (.01, 0.2)$, $\partial m/\partial t < 0$ i.e., abatement effect is small. For this very same range of t, $\partial k/\partial t$ can be either positive of negative as discussed in the main body of the article.

Now, for $t \in (0.2, 0.4)$, abatement effects are large enough and so $\partial m/\partial t > 0$, $\partial k/\partial t > 0$. A large enough abatement effect implies that additional firms enter the market via an increase in the emission tax and, also, an increase in the share of new firm acquisitions. The reason for this is that higher profits (via the large abatement effect) prompts firms to enter

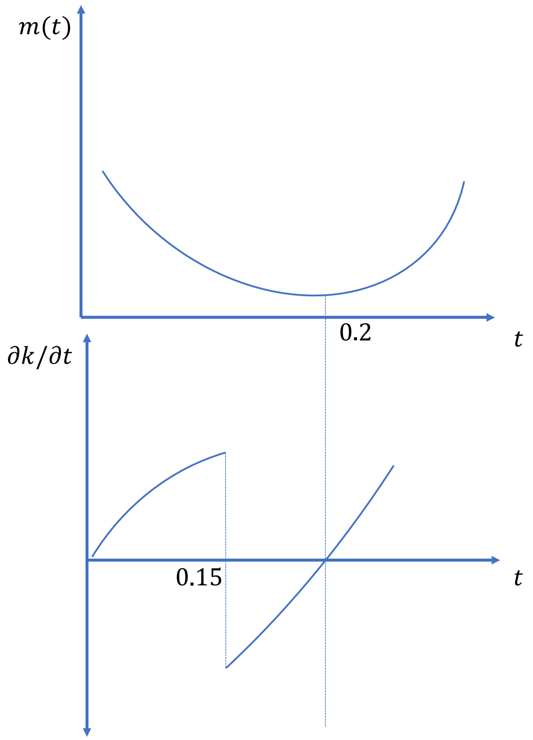

Fig. 4 Number of new firms, m, share of new firm acquisitions, k and the emission tax, t: $t \in (.01, 0.2)$

the market and the incumbent firm to acquire a larger share of the now more profitable firms.

Next, we describe the solution to the model we used to derive the above figures and share $q^o/(q+q^o) = 30\%$. First, we combine first-order conditions (1) and (2) into one equation; we also substitute the demand function, P, into this newly derived equation. Second, we do the same with Eqs. (3) and (4), where we substitute P^o. From these two equations we solve simultaneously for $q(m, k, t)$, $q^o(m, k, t)$. Second, we substitute the expressions for $q(m, k, t)$, $q^o(m, k, t)$ obtained in the previous step into equation $\hat{\pi} = \pi$ (where $\pi_j = \pi, \forall j$). This yields $k(m, t)$. Third, we simplify the zero-profit condition, $\pi^o = 0$, using Eqs. (3) and (4); then, we substitute $q^o(m, k, t)$ and $k(m, t)$, which yields $m(t)$. Fourth, substituting $m(t)$ back into $k(m, t)$ gives $k(t)$. Subsequently, we substitute $m(t)$ and $k(t)$ back into $q(m, k, t)$, $q^o(m, k, t)$, which gives $q(t)$ and $q^o(t)$. We then use $q(t)$ and $q^o(t)$ to calculate the share $q^o/(q^o + q)$ for range $t \in (.01, 0.3)$. This share is approximately at 30%.

Acknowledgements Luis Gautier would like to thank the Ministerio de Universidades, Spain and Next Generation EU for financial support through the fellowship Ayudas María Zambrano. The authors would like to thank the anonymous reviewers and guest editors for valuable comments and suggestions.

Author Contributions All authors contributed to the study conception, design, investigation, formal analysis, methodology. Material preparation and analysis were performed by M. Fikru and L. Gautier. The first draft of the manuscript was written between M. Fikru and L. Gautier. All authors read and approved the final manuscript.

Funding Funding for open access publishing: Universidad Málaga/CBUA. No funding was received for this study.

Availability of Data and Material Not applicable.

Data Availability Not applicable.

Declarations

Conflict of interest The authors declare they have no competing interests.

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent for Publication Not applicable.

References

Blair RD, Haynes JS (2011) The efficiencies defense in the 2010 horizontal merger guidelines. Rev Ind Organ 39(1–2):57–68

Cabral LM (2003) Horizontal mergers with free-entry: why cost efficiencies may be a weak defense and asset sales a poor remedy. Int J Ind Organ 21(5):607–623

Carraro C, Katsoulacos Y, Xepapadeas A (1996) Environmental policy and market structure. Kluwer Academic Publishers, Dordrecht
Creti A, Sanin ME (2017) Does environmental regulation create merger incentives? Energy Policy 105:618–630
Davidson C, Mukherjee A (2007) Horizontal mergers with free entry. Int J Ind Organ 25:157–172
Erkal N, Piccinin D (2010) Welfare reducing mergers in differentiated oligopolies with free entry. Econ Rec 86(273):178–184
Farrell J, Shapiro C (1990) Horizontal mergers: an equilibrium analysis. Am Econ Rev 107–126
Fikru M, Gautier L (2016) Mergers in Cournot markets with environmental externality and product differentiation. Resour Energy Econ 45:65–79
Fikru M, Gautier L (2017) Environmental policy and mergers in oligopoly markets with product differentiation. J Econ 122(1):45–65
Fikru M, Gautier L (2020) Cross-country emission tax effect of mergers. Arthaniti J Econ Theory Pract 22(1)
Fikru MG, Lahiri S (2013) Can a merger take place among symmetric firms? Stud Microecon 1(2):155–162
Garcia R, Lessard D, Singh A (2014) Strategic partnering in oil and gas: a capabilities perspective. Energ Strat Rev 3:21–29
Gelves JA (2014) Differentiation and cost asymmetry: solving the merger paradox. Int J Econ Bus 21(3):321–340
Gomes M, Marsat S (2018) Does CSR impact premiums in M &A transactions? Financ Res Lett 26:71–80
Jacqz IB (2020) Essays on air toxics: distribution, drivers, and consequences. The University of Wisconsin-Madison
Kao T, Menezes F (2010) Welfare-enhancing mergers under product differentiation. Manch Sch 78(4):290–301
Katsoulacos Y, Xepapadeas A (1995) Environmental policy under oligopoly with endogenous market structure. Scand J Econ 97:411–420
Kumar BR (2012) Mergers and acquisitions in the energy sector. In: Mega mergers and acquisitions. Palgrave Macmillan, London
Kwon O, Lim S, Lee DH (2018) Acquiring startups in the energy sector: a study of firm value and environmental policy. Bus Strateg Environ 27(8):1376–1384
Lee SH (1999) Optimal taxation for polluting oligopolists with endogenous market structure. J Regul Econ 15:293–308
Lu J (2021) Can the green merger and acquisition strategy improve the environmental protection investment of listed company? Environ Impact Assess Rev 86:106470
Matsumura T, Okumura Y (2014) Comparison between specific taxation and volume quotas in a free entry Cournot oligopoly. J Econ 113:125–132
Nocke V, Whinston MD (2013) Merger policy with merger choice. Am Econ Rev 103(2):1006–33
PricewaterhouseCoopers (2012) The integration of environmental, social and governance issues in mergers and acquisitions transaction. Trade buyers survey result. December 2012. Prepared by PricewaterhouseCoopers with support from Principles for Responsible Investment
Qiu LD, Zhou W (2006) International mergers: incentives and welfare. J Int Econ 68(1):38–58
Requate T (1997) Green taxes in oligopoly if the number of firms is endogenous. Finanzarchiv Public Finance Anal 54:261–280
Requate T (2006) Environmental policy under imperfect competition. In: Tietenberg T, Folmer H (eds) The international yearbook of environmental and resource economics 2006/2007. Edward Elgar Publishing Limited, UK, pp 120–207
Salant SW, Switzer S, Reynolds RJ (1983) Losses from horizontal merger: the effects of an exogenous change in industry structure on Cournot–Nash equilibrium. Q J Econ 98(2):185–199
Spector D (2003) Horizontal mergers, entry, and efficiency defenses. Int J Ind Organ 21:1591–1600
Xiao B, Fan Y, Guo X (2021) Dynamic interactive effect and co-design of SO2 emission tax and CO2 emission trading scheme. Energy Policy 152:112212
Yu P (2020) Carbon tax/subsidy policy choice and its effects in the presence of interest groups. Energy Policy 147:111886
Zheng D, Yuan Z, Ding S, Cui T (2021) Enhancing environmental sustainability through corporate governance: the merger and acquisition perspective. Energy Sustain Soc 11(1):1–15