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The impact of renewable energy use on firm profit

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ABSTRACT

Firms buy renewable energy at premiums and report environmental concerns as motivation to do so. The bulk of the literature on environmental corporate social responsibility suggests that this type of behavior even results in higher profit. However, a product-differentiation framework with perfect competition predicts that renewable energy use has no effect on profit. This paper tests this prediction by investigating the relationship between firms' renewable energy use and profit on the basis of panel data for 920 firms over 2014–2018. We do not find evidence for an impact of renewable energy use on profit. Hence, a 'win-win' in the form of higher profit and a better environment does not seem to exist. In addition, the results appear to suggest that firms do not have a positive willingness to pay for renewable energy as contribution to the environment. This implies that firms are only willing to contribute to climate-change mitigation through buying renewable energy when this is aligned with the profit-maximization objective.

1. Introduction

An increasing number of firms uses renewable energy with the intention to "combat climate change" (Apple, 2018), "contribut[e] to the reduction of carbon [emissions]" (Nestle, 2018) or "reduc[e] the environmental footprint" (Volkswagen, 2017). These public announcements seem to suggest that these firms are motivated by environmental concerns when they buy renewable energy, particularly considering that renewable energy is generally more expensive than non-renewable energy. For example, in the case of renewable electricity (applying to the three cited firms), firms that want to claim the use of renewable electricity typically acquire renewable electricity certificates in addition to the electricity itself. The wholesale price of European renewable electricity certificates (Guarantees of Origin) was approximately €2 per MWh in 2018 (Greenfact, 2018). Prices of certain specific certificates are even much higher, such as Dutch wind certificates, which had a price of more than €7 per MWh in 2018.[1]

Considering that buying these renewable energy certificates does not affect at all firms' technological processes, the question emerges how renewable energy use is related to the general objective of the firm according to microeconomic theory, which is to maximize profit. More generally, this question appears relevant for most environmental corporate social responsibility (CSR) actions of firms. CSR may be referred to as actions that are beneficial to society, not directly beneficial to the firm and not required by law (McWilliams and Siegel, 2001). Environmental CSR can be considered the subgroup of CSR actions which are related to environmental concerns, such as reducing the use of fossil energy in order to contribute to the mitigation of climate change. This paper regards renewable energy use as a specific type of environmental CSR: it benefits society through climate change mitigation while it generally does not provide direct benefits to the firm (i.e. lower costs) and is not required by law.

An extensive amount of papers empirically investigates the impact of environmental CSR on firm profit, or, comparably, the impact of environmental performance on financial performance. While some papers find no relationship (e.g. Petitjean, 2019; Brzeszczynski, Ghimire, Jamasb, and McIntosh, 2019), or even a negative impact (e.g. Oberndorfer, Schmidt, Wagner, and Ziegler, 2013), a large amount of papers find a positive impact of CSR on profit (e.g. Konar and Cohen, 2001; Kang, Germann, and Grewal, 2016). This positive relationship is corroborated in several meta-analyses, both for environmental CSR in particular (e.g. Dixon-Fowler, Slater, Johnson, Ellstrand, and Romi, 2013; Margolis, Elfenbein, and Walsh, 2009) and CSR in general (e.g. Margolis, Elfenbein, and Walsh, 2009; Margolis and Walsh, 2001; Orlitzky, Schmidt, and Rynes, 2003). A positive impact of CSR on profit

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[1] See Hulshof, Jepma, and Mulder (2019) for more information on renewable energy certificate prices in Europe. For reference, the average wholesale electricity price was about €45 per MWh in the past decade in Northwest Europe.

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seems to imply the existence of a 'win-win': CSR activities that benefit the environment are associated with higher firm profit as well.

Taking on a microeconomic perspective, a structural positive effect of renewable energy use on profit may not be expected. On the one hand, renewable energy use can enable the firm to differentiate itself from competitors such that it can serve consumers with a higher willingness to pay (WTP) and charge them higher prices. On the other hand, competition for those consumers is expected to drive down prices to the level of marginal costs.[2] Furthermore, regarding firms' reported environmental concerns, it appears questionable as to whether firms are willing to use renewable energy at the expense of profit, as this directly contradicts the assumption that firms maximize profit. But if firms would be willing to use renewable energy at the expense of profit, the decline in profit may be seen as the revealed willingness to pay of firms to contribute to climate-change mitigation.

The main question we address is: what is the impact of renewable energy use on firm profit? The main contribution of this paper is that, to the best of our knowledge, it is the first empirical analysis of the impact of renewable energy use on firm profit. The paper also contributes to the broader literature on the relationship between financial and environmental performance by using a concrete measure of a specific type of environmental CSR, instead of the frequently used indicator variables for environmental CSR (such as the Kinder, Lydenberg, Domini & Co. (KLD), environmental, social and governance (ESG), or ASSET4 score indicators), of which it is unclear whether they accurately reflect the true level of environmental performance (e.g. Dixon-Fowler, Slater, Johnson, Ellstrand, and Romi, 2013).

This paper empirically investigates the impact of renewable energy use on firm profit. Our analytical framework relies on the theory of product differentiation in a profit-maximization framework, as discussed in a seminal paper by Rosen (1974). This framework appears appropriate since, from a profit-maximization perspective, the only justification for using renewable energy is that the firm can differentiate itself from competitors (e.g. gain a better reputation) and serve consumers with a higher willingness to pay for this type of product quality, as renewable energy is more expensive and provides no technological advantages. Based on this analytical framework, we expect no impact of renewable energy use on profit. Our empirical analysis tests this prediction. If the empirical findings are not in accordance with this prediction, this might suggest that other explanations for renewable energy use by firms are more appropriate, for instance altruistic environmental concerns.

The empirical analysis uses panel data for the period 2014–2018. The panel consists of 920 firms from 59 countries from a very large number of sectors. Our estimates of the impact of renewable energy use on firm profit are not statistically significant. These results do not corroborate the positive impact that has been established in the literature, and we conclude that there seems to be no 'win-win' from renewable energy use in the form of higher profit and a better environment. Instead, the impact appears to be neutral, as predicted by the theoretical framework, which would suggest that firms do not sacrifice profit when they use renewable energy. However, given that the coefficients are estimated with relative imprecision, we recommend further research to verify these findings.

The remaining of this paper is organized as follows. The second section reviews the theoretical and empirical literature. The third section discusses the analytical framework. The fourth section describes the methods applied in this paper, in particular the empirical model, data and estimation method. The fifth section provides the results and discussion. Section six concludes.

[2] This may not be true in product-differentiation settings with entry barriers for selecting/switching between differentiation strategies. In Section 3, the paper argues that these are not relevant for differentiation on the basis of renewable energy.

2. Literature review

A, by now substantial, literature has emerged that discusses the impact of environmental CSR on firm profit. This section first discusses the link between profit and (environmental) CSR from a theoretical perspective. Consequently, this section discusses the findings in the empirical literature. Finally, this section discusses renewable energy use by firms in particular. Considering the similarity between papers that focus on the general CSR-profit relationship and the environmental CSR-profit relationship, this section discusses papers from both the general CSR and environmental CSR literature.

2.1. Theoretical literature

Economic theory has suggested two main theoretical explanations for the presence of (environmental) CSR goods in firms' profit-maximizing bundle of inputs. First of all, (environmental) CSR can be part of profit maximization when it enables product differentiation. In contrast to firms active in markets with homogeneous goods, firms active in markets with differentiated goods may be able to charge a higher price than competitors (e.g. Rosen, 1974). Taking on a theory of the firm perspective, McWilliams and Siegel (2001) theorize that CSR expenditure can result in product attributes that are valued by consumers. The authors propose that firms, like for other inputs, trade-off the costs and benefits of CSR expenditure and select the quantity of CSR where the marginal costs and benefits are equalized. Considering the possibility to switch between CSR strategies, they theorize that CSR does not have an effect on profit. A primary example of how firms differentiate themselves from competitors is reputation building through (environmental) CSR expenditure (e.g. Siegel and Vitaliano, 2007; McWilliams and Siegel, 2011).

Secondly, the profit-maximizing way to produce any quantity is where the production costs are minimized. Besides that several clean production technologies or inputs may be cheaper than polluting alternatives,[3] some authors have pointed out more subtle mechanisms through which environmental CSR can be part of cost-minimization. Porter and Van der Linde (1995) note that many types of environmental CSR investments are characterized by high initial investment costs which ultimately lead to cost reductions that offset the initial investment costs.[4] Another argument is that costly environmental CSR may prevent governments from imposing even more costly regulation (e.g. Davis, 1973; Carroll and Shabana, 2010).

2.2. Empirical evidence

An extensive empirical literature regarding the impact of environmental CSR in particular or CSR in general and profit has emerged. Within this empirical literature, two major strands of papers exist. A first strand tries to relate measures of profit (e.g. net income or return on assets) to measures of (environmental) CSR (predominantly indicators of environmental CSR based on the KLD, ESG or ASSET4 scores).[5] A

[3] E.g. energy efficiency measures. It must be noted that it is somewhat doubtful whether these type of production inputs can be considered as CSR because, in addition to external benefits, they also generate direct private benefits to the firm. This is not the case for renewable energy considering that it is generally more expensive than non-renewable energy.

[4] Porter and Van der Linde (1995) also propose that regulation is required for firms to be willing to invest in many types of CSR because they suggest that firms generally fail at making optimal choices inter-temporally, i.e. fail at minimizing costs/maximizing profit over the long run.

[5] KLD, ESG and ASSET4 scores are typically managed by a research firm. This research firm scores and ranks other firms on the basis of a set of performance indicators relating to environmental, social and governance matters. Examples of two performance indicators in the KLD database are: (i) whether a company has "…notably strong pollution prevention programs including both emissions reductions and toxic-use reduction programs"; and (ii) whether a company uses recycled raw materials or is a major factor in the recycling industry in some other way.

second strand tries to relate stock market performance (e.g. abnormal returns or Tobin's Q) to measures of (environmental) CSR (typically inclusion in a sustainability index or indicators of environmental CSR based on the KLD, ESG or ASSET4 scores). Some paper have used both measures of profit and measures of stock market performance in their analysis. With respect to the difference between environmental and general CSR, papers focusing on the former generally measure CSR over environmental aspects only, whereas papers focusing on the latter measure CSR over all aspects. In other respects, the methodology is typically very similar.

In both strands of literature, the empirical evidence is not fully consistent between studies. For the strand using measures of stock market performance, a large number of studies finds a positive relationship between (environmental) CSR and profit (e.g. King and Lenox, 2001; Kang, Germann, and Grewal, 2016). A considerable number of other studies find that no relationship exists (e.g. Petitjean, 2019; Brzeszczynski, Ghimire, Jamasb, and McIntosh, 2019; Ng and Zheng, 2018). In addition, a very small minority of studies reports a negative relationship (e.g. Oberndorfer, Schmidt, Wagner, and Ziegler, 2013; Meznar, Nigh, and Kwok, 1994). Likewise, for the strand using accounting-based measures of profit, many studies report a positive relationship (e.g. Russo and Fouts, 1997; Waddock and Graves, 1997), whereas other studies find no significant relationship (e.g. Petitjean, 2019). The positive relationship is confirmed by several meta-analyses, which typically include papers that use profit measures as well as stock market-performance measures. This is the case for environmental CSR in particular (e.g. Dixon-Fowler, Slater, Johnson, Ellstrand, and Romi, 2013; Margolis, Elfenbein, and Walsh, 2009), and for CSR in general (e.g Margolis, Elfenbein, and Walsh, 2009; Margolis and Walsh, 2001; Orlitzky, Schmidt, and Rynes, 2003). In addition, the type of measure for firm performance (stock-market or profit based) does not appear to affect these meta-analytic results (Dixon-Fowler, Slater, Johnson, Ellstrand, and Romi, 2013).

Barnett and Salomon (2012) theorize and empirically find a U-shaped relationship between CSR and firm profit. They propose that, in order to profit from CSR actions, the level of CSR needs to surpass a certain threshold for otherwise the firm's stakeholders will not react in a profitable manner. Their argument is based on a stakeholder argument, namely that a firm's capability to influence its stakeholders depends on the level of CSR. The paper argues that, at low levels of CSR, a firm has few abilities to influence its stakeholders because those stakeholders will not perceive social actions by the firm as very credible and therefore not respond in a profitable manner. In contrast, at high levels of CSR, a firm has the ability to influence its stakeholders because those stakeholders will perceive social actions by the firm as credible and therefore respond in a profitable manner (in this case “such actions are in consonance with the firms character”).

Also related to this paper is Ziegler, Busch, and Hoffmann (2011), who find that the stock market performance of firms who disclose their response to climate change is better than the stock market performance of firms who do not disclose their response.

Many papers in this literature have been criticized for the typical use of indicator variables for (environmental) CSR, often based on ESG, KLD and ASSET4 scores. This type of indicator variable is usually based on ranking firms on a large number of CSR-related aspects. The scores on the various aspects are then transformed into a single firm-level CSR score. These indicator variables have mainly become popular because it is difficult to measure CSR objectively. Inherently, there is a degree of subjectivity and arbitrariness present in the methodologies underlying such indicators (e.g. selection of aspects and aspect score calculation). Because of these problems, the validity of these indicators to represent actual environmental or social performance has been questioned (e.g. Dixon-Fowler, Slater, Johnson, Ellstrand, and Romi, 2013; Margolis and Walsh, 2001; Chatterji, Levine, and Toffel, 2009; Semenova and Hassel, 2015). One notable exception is Konar and Cohen (2001), who use data regarding emissions of toxic chemicals and pending environmental lawsuits and also find a positive relationship with profit.

A second critique is the widespread (incorrect) use of ratio variables in this literature, both as dependent and independent variable (e.g. return on assets or toxic chemical emissions per dollar revenue) (Barnett and Salomon, 2012), which may lead to spurious results in regression analysis (e.g. Kronmal, 1993).

Another branch of papers has verified the direction of causality in the relationship between profit and CSR. The concern of these papers is that CSR activities may be determined by profitability, rather than the other way around, because these activities represent “inessential” expenditure. If valid and unaccounted for, this reverse causality problem could lead to biased estimates from conventional estimation techniques. However, explicitly addressing the direction of causality, Kang, Germann, and Grewal (2016) and Scholtens (2008) find evidence that causality runs from CSR to profit and not the other way around.

2.3. Renewable energy use by firms

In recent years, there has been a marked increase in the demand for renewable energy from firms. This can be seen for example from the steep increase in participation by firms in voluntary renewable energy programs in which they pledge or articulate their intention to increase their renewable energy use. Two primary examples are the U.S. EPA's Green Power Partnership (GPP) program and the RE100 initiative. The former experienced an increase in the number of participants from 656 in 2006 to 1532 in 2018 (including small, medium and very large firms from a wide number of sectors). Collectively, participants consumed 55TWh of renewable electricity in 2018 (EPA, 2019).[6] The RE100 initiative experienced an increase from 50 participating firms in 2015 to 155 in 2018 (including mostly large firms from a large number of sectors) with an aggregate renewable electricity consumption of 72TWh in 2017 (RE100, 2018). Based on survey findings, PWC (2016) reports that meeting sustainability goals and reducing greenhouse gas emissions is the primary motivation for firms in the U.S. to buy renewable energy.

The primary tool for firms to consume renewable energy is the procurement of renewable energy certificates (RECs), which has become the dominant market mechanism for consumption of renewable electricity (Hulshof, Jepma, and Mulder, 2019). RECs are administered to renewable energy producers, which can then be sold separately from the energy to end-users who wish to claim the consumption of renewable energy. Firms buy RECs either (i) directly as unbundled product, i.e. separately from their electricity product, or (ii) as a bundled product consisting of both RECs and electricity from a retailer or producer. A third way to claim the consumption of renewable electricity, which does not involve the explicit purchase of RECs, is (iii) generating renewable electricity on-site at the firm.[7] Method (i) and (ii) accounted for 95% and 97% of the renewable electricity consumption of GPP partners in 2018 and RE100 participants in 2017, respectively (EPA, 2019; RE100, 2018).

3. Analytical framework

This paper's analytical framework is based on the seminal paper about vertical product differentiation by Rosen (1974). Products are vertically (as opposed to horizontally) differentiated when, at a given price, everybody prefers a product (or is indifferent) when more of a particular characteristic is present. This appears to be the suitable framework for our analysis because vertical product differentiation is

[6] For reference, total electricity consumption in 2017 in Chile, Italy and the U.S. was 75TWh, 315TWh and 4098TWh, respectively (IEA, 2019).

[7] Although method (iii) does not involve the explicit purchase of RECs, the opportunity cost of consuming on-site generated renewable electricity includes the foregone REC price.

the principal mechanism through which renewable energy use relates to (economic) profit of the firm. It is clear that some individuals prefer goods with environmental-friendly attributes (e.g. Bjørner, Hansen, and Russell, 2004) and, despite that some individuals may be indifferent, there seems to be no reason to dislike the use of renewable energy in production. This section provides an interpretation of Rosen's model when goods are vertically differentiated on the basis of firms' renewable energy use with several assumptions that are specific to this setting. We discuss the main insights and implications for the relationship between firm profit and renewable energy from adopting this framework.

A key element in Rosen's model is the dependence of the market price (p) on the presence of a number (n) of valuable product characteristics ($z = (z_1, z_2, \cdots, z_n)$), which he refers to as the hedonic price function $p(z)$. Here, it is assumed that products are differentiated on the basis of a single attribute, renewable energy ($z = RE$). Firms are price takers in input and output markets, but face different market prices when they use more or less *RE*. We will make the specific assumption that firms can modify the product's renewable energy characteristic by simply buying the desired amount of renewable energy certificates at the prevailing market price, reflecting actual practice. In terms of the firm's cost function $C(M, RE)$, where M is the quantity produced, this translates to assuming that the marginal cost of adding renewable energy is constant i.e. $\frac{\partial C}{\partial RE} > 0$ and $\frac{\partial^2 C}{\partial RE^2} = 0$. Moreover, buying renewable energy certificates does not lead in any way to changes in the physical production process and there are basically no interactions with other production inputs.[8] Further, we assume that firms have the same cost function. While this may not reflect reality for other product characteristics and inputs, it can be justified for the case of renewable energy on the basis that firms do not transform other inputs into the renewable energy characteristic but simply buy it from certificate retailers.

Firms then maximize profit $\pi = Mp(RE) - C(M, RE)$ with respect to *RE* and *M*. The first order conditions that yield the optimum choices of $M = M^*$ and $RE = RE^*$ are given by:

$$p(RE) - \frac{\partial C}{\partial M} = 0 \quad (1)$$

and

$$M \frac{\partial p}{\partial RE} - \frac{\partial C}{\partial RE} = 0 \quad (2)$$

Eq. (2) gives the relationship between profit and renewable energy use, when evaluated at M^*. The first term ($M \frac{\partial p}{\partial RE}$) gives the marginal revenue of increasing *RE* whereas the second term ($\frac{\partial C}{\partial RE}$) is the marginal cost of increasing *RE*. Notice that the marginal cost of *RE per unit of output* is equal to $\frac{\partial C}{\partial RE}/M^*$. This is the firm's minimally required price increase to be willing to increase its use of *RE*, i.e. the marginal reservation price for *RE*. Because of the assumption that firms have the same cost function, this is identical for all firms. According to (2), in the optimum, the marginal cost and revenue per unit should be equal, i.e. $\frac{\partial p}{\partial RE} = \frac{\partial C}{\partial RE}/M^*$. Furthermore, because we assume a competitive market, prices will equal the producers' reservation prices for *RE* and *M*. This implies that $\frac{\partial p}{\partial RE}$ is fully determined by $\frac{\partial C}{\partial RE}/M^*$.[9] Under these assumptions,

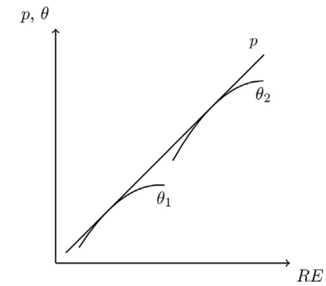

Fig. 1. Producer (p) and consumer (θ_i) reservation prices for the renewable energy characteristic.

the hedonic price curve and the producers' common *RE* marginal reservation price curve coincide and (2) is satisfied at any choice of *RE*. Moreover, since the marginal cost of certificates is constant, the slope of the marginal reservation price curve and therefore the hedonic price curve is also constant. In terms of (2), $\frac{\partial^2 p}{\partial RE^2} = 0$ because $\frac{\partial^2 C}{\partial RE^2} = 0$ by assumption.[10] Fig. 1 draws the relevant producer reservation price curve ($p(RE)$) as a function of the renewable energy characteristic.[11]

From the perspective of some consumers, more of the renewable energy input may be preferred and the willingness to pay of these individuals increases with the amount of renewable energy accordingly. However, since buying a good with more renewable energy (at a higher price) means lower consumption of other goods, the marginal willingness to pay for the *RE* characteristic is decreasing, conform the usual properties of a utility function. In terms of Fig. 1, this can be shown by introducing a special type of consumer indifference curve, which Rosen calls the bid curve (θ). The bid curve reflects a consumer's willingness to pay for the good at different *RE* levels, while holding the level of utility constant.[12] As with conventional indifference curves, a whole family of parallel bid curves exist. Consumers prefer bundles to the south-east corner (i.e. a lower price for a given amount of *RE*) but are constrained by the market price. Their optimal choice is characterized by a tangency condition between their indifference curve and the hedonic price curve (essentially the budget constraint), corresponding here to the competitive firm's reservation price curve. Fig. 1 draws the bid curves of two example consumers, which optimally choose two different levels of *RE*. When the preferences of consumers for the *RE* characteristics are very heterogeneous or “spread out”, as is assumed in Rosen (1974) and here, the points of tangency with the producer reservation price curve occur at all levels of *RE*. In other words, at any choice of *RE*, a firm can find consumers that prefer exactly that type.

What are the implications for the impact of renewable energy use on profit? The outcome of the model is that the choice of *RE* does not matter for profit as firms are always exactly compensated for the increased costs of using more renewable energy. By increasing *RE*, costs increase

[8] The assumptions on the cost function are chosen to reflect differentiation on the basis of renewable energy in practice. This includes assuming there exist no entry barriers in the form of a fixed cost associated with choosing a certain renewable energy/quality level, as in Shaked and Sutton (1982, 1987). With renewable energy, firms change the desired amount of certificates and pay the associated marginal certificate price when choosing/changing the desired quality level instead of paying a significant fixed costs.

[9] Individual firms take the hedonic price curve and its slope as exogenous as they are assumed to be price takers.

[10] Assuming non-constant marginal cost of renewable energy merely changes the shape of the reservation price curve (e.g. convex), but not the qualitative conclusions regarding the expected relationship between profit and renewable energy from this theoretical framework.

[11] Where relevant refers to the reservation price curve corresponding to the competitive-industry profit level (π_{pc}). Rosen (1974) shows that a whole family of parallel reservations price curves exist (i.e. all with slope $\frac{\partial C}{\partial RE}/M^*$), each corresponding to a different profit level. From assuming a competitive market, the relevant reservation price is the one associated with π_{pc}.

[12] In Figure 1, the vertical axis measures the amount spend on the good, as it is assumed that consumers buy one unit, which therefore equals the foregone expenditure on other goods. The bid curve is therefore an inverted conventional indifference curve (trading off consumption of the good with varying levels of the *RE* attribute versus consumption of other goods), with slope equal to the inverse of the slope of a conventional indifference curve.

but, following the price increase, revenues also increases in an exactly offsetting manner.[13] In other words, this theoretical framework predicts that there is no impact of renewable energy use on profit.[14]

One of our critical (but arguably realistic) assumptions that drives this prediction is that firms have access to exactly the same technology/cost function to add the renewable energy characteristic, namely by simply buying the desired amount of certificates at a constant price. In contrast, assuming differences exist in firms' cost function, the general model in Rosen (1974) predicts that there will be a single optimal choice of *RE* for an individual firm and deviating in any direction from the optimum would hurt profit.

The subsequent empirical analysis tests the prediction of a neutral impact of renewable energy use on profit, which we derived from taking on a profit-maximization perspective with vertical product differentiation in a perfectly competitive environment. Given that alternative explanations for renewable energy use cannot be true at the same time (e.g. one alternative explanation being that firms engage in green behavior for environmental reasons and at the expense of profit), we investigate the specific explanation that renewable energy use follows from profit maximization and that firms will only do so if they are compensated for it (in an offsetting manner due to competition).

4. Method

4.1. Empirical model

Using panel data, we estimate an empirical model that relates firm profit (π) to renewable energy use (RE). The empirical model assumes that firms have the cost function $C(RE, M(K, L, TE))$: firms use capital (K), labor (L) and (total) energy (use) (TE) to produce the quantity of output (M), and can adjust the quality of output by procuring RE. We do not impose structure on the revenue or cost functions. Instead, we estimate a reduced-form regression model that relates profit to the four production factors: RE, K, L and TE[15]:

$$\pi_{ti} = \beta_0 + \beta_1 RE_{ti} + \beta_2 K_{ti} + \beta_3 L_{ti} + \beta_4 TE_{ti} + c_i + \boldsymbol{\alpha Y}_{ti} + \varepsilon_{ti} \quad (3)$$

where t refers to the time period, i to the firm and c to an unobserved time-invariant firm-specific effect. In this case, c may capture differences in the unobserved ability of firms' management. **Y** is a vector of year-sector interaction dummies which are equal to one for firm i in year t if the firm belongs to the respective sector and zero otherwise. This may capture for example macroeconomic fluctuations pertaining to a specific sector. ε is an error term which is assumed to be independent and identically distributed with a mean of zero.

To test for the presence of a U-shaped relationship between π and RE, as found by Barnett and Salomon (2012), we estimate a second specification that includes a quadratic RE term:

$$\pi_{ti} = \beta_0 + \beta_1 RE_{ti} + \beta_{11} RE_{ti}^2 + \beta_2 K_{ti} + \beta_3 L_{ti} + \beta_4 TE_{ti} + c_i + \boldsymbol{\alpha Y}_{ti} + \varepsilon_{ti} \quad (4)$$

The empirical models deliberately omit R&D expenditure as control variable, which is suggested to be included by McWilliams and Siegel (2000) for empirical models linking CSR to profit. As the procurement of RECs from producers or retailers is a simple administrative act, renewable energy consumption is typically not expected to be relevant for firms' product innovations stemming from R&D expenditure. Including R&D expenditure does not materially change our conclusion regarding the impact of renewable energy use on profit. The first two columns of Table A.1 in Appendix A report the results of the model with R&D expenditure included as control variable. Another control variable that has often been included in the CSR literature that we omit is the level of debt. Including debt also does not materially change our conclusions, see the last two columns of Table A.1 in Appendix A.

4.2. Data

The data for this analysis comes from firms' financial and environmental reports over the period 2014–2018, which we collect using Bloomberg. For this period, renewable energy use (in GWh) is reported for 973 firms in one or more years, resulting in a total number of annual firm-year observations for this variable of 2702 (including observations of zero renewable energy use).[16] The data on renewable energy use is complemented with data for the other variables in (3): net income (in thousand US$) as a measure of profit,[17] total energy use (in GWh),[18] assets (in million US$) as a measure of capital and the number of employees (in full-time equivalents) as a measure of labor.

The final panel dataset is unbalanced due to one or more missing observations in most of the variables. In total, the final sample includes 2554 firm-year observations for 911 firms. Firms from all continents and sectors are included in the sample, where sectors are distinguished according to the Industry Classification Benchmark (ICB) by FTSE Russell. The ICB classification encompasses 114 sub-sectors, 41 sectors, 19 super-sectors and 10 industries, out of which 104, 39, 19 and 10 are represented in the sample. The ICB sectors are used for construction of the year-sector dummy variables (195 in total of which one is omitted in the estimations). Table 1 reports details about the geographical and industrial characteristics of the firms in our sample. Table 2 reports several key descriptive statistics of the variables.

Reporting about renewable energy use is voluntary and the incentive to report seems more obvious for firms that use considerable amounts of renewable energy (i.e. green firms) than for firms that do not. Therefore, a worry may be that the sample only includes relatively green firms, thereby introducing a potential selection bias. However, the kernel density plot of the distribution of the share of renewable energy (as percentage of total energy use) depicted in Fig. 2 in Appendix B shows that the large majority of the firm-years in the sample have a renewable energy share of or close to zero. Our results could still be prone to selection bias when these zero observations are ‘early’ observations of firms who start reporting positive renewable energy use in later time periods. However, 46% of the ‘zero’ observations for renewable

[13] We assume in the model that consumers have perfect information on product qualities in terms of *RE*. In practice, information about the level of *RE* is usually not directly observed from a product, but may be accessed through annual or environmental reports. Suppose that the assumption is violated and information asymmetry regarding *RE* qualities exists. One would then expect that consumers lower their willingness-to-pay for products with a positive level of *RE* and that, as a consequence, adverse selection arises (cf. Akerlof, 1970). In terms of Figure 1, because of information asymmetry, the consumer reservation price curves shift to the left. The intrinsic costs of producing RE have not changed. In effect, the tangency points will shift to the left, resulting in products of relatively lower RE quality and lower average prices (i.e. adverse selection occurs). Regarding the relationship between profit and renewable energy use, information asymmetry has no effect because it is still predicted to be neutral.

[14] From assuming there is perfect competition between firms at every level of *RE*, this theoretical framework implies that there exist few incentives to switch from *RE* strategy. However, our theoretical framework describes an equilibrium outcome and transition dynamics may partly explain the incentives for firms to switch from *RE* strategy. Consider, for example, that consumer preferences change towards preferring more green types. This change may create new niche markets that previously did not exist. First movers in these new niche markets may earn profit in the short run, providing an explanation for why firms may switch from *RE* strategy. With perfect competition and considering how easy it is to switch to/copy another *RE* strategy, these profit opportunities are expected to dissipate relatively quickly."

[15] The empirical model implicitly assumes that the relationship between renewable energy use and profit, as given by β_1, is the same for all firm sizes. This is in line with our theoretical framework. However, we have also estimated equation (3) with interactions included between *RE* and *K*, *L* and *TE* (separately) to investigate whether the marginal effect of renewable energy use differs with firm size. These interaction terms (and β_1) are not statistically significant in all three robustness estimations.

[16] Note that this includes all types of renewable energy, such as renewable electricity, renewable gas, renewable hydrogen etc.

[17] I.e. after taxes, interest payments, depreciation and all other expenses. Note that this is a measure of accounting profit and not economic profit.

[18] Including all types of energy.

Table 1
Number of firm-years in sample by geography and industry.

	World	North America	South America	Europe	Africa	Asia	Oceania
All sectors	2554	608	177	1071	35	604	59
Oil & gas	88	21	9	33	0	25	0
Basic materials	316	84	35	93	5	81	18
Industrials	551	108	27	246	5	154	11
Consumer goods	429	74	26	181	9	135	4
Health care	124	46	3	47	2	26	0
Consumer services	180	51	8	92	10	19	0
Telecommunications	96	10	11	56	1	13	5
Utilities	135	24	46	51	0	14	0
Financials	458	115	12	246	3	61	21
Technology	177	75	0	26	0	76	0

Source: Bloomberg.

Table 2
Descriptive statistics.

	Mean	SD (within)	Minimum	Maximum
Net income (mln US$)	1300	3939 (2235)	−16,265	94,209
Renewable energy use (GWh)	1423	5930 (1935)	0	106,884
Total energy use (GWh)	10,672	37,656 (4788)	0.2	563,957
Share of renewable energy	18.0%	24.8% (6.9%)	0%	100%
Assets (mln US$)	79,653	259,548 (18,998)	22	2,622,532
Employees (fte)	45,795	73,836 (8104)	5	706,730

Source: Bloomberg.

energy use in our sample are from firms that never reported positive renewable energy use in the observed period.

4.3. Estimation method

The analysis applies both a within-estimation procedure as well as a random-effects estimation procedure to estimate the coefficients of Eqs. (3) and (4). A within-estimation procedure is appropriate when the unobserved time-invariant firm-specific effect (c) is correlated with the independent variables, which is not unlikely. A drawback of using the within-estimator is that it only exploits variation in renewable energy use within firms, of which there is considerably less when compared to variation between firms (see Table 2). Therefore, we also apply a random-effects estimation procedure, which exploits both sources of variation. The random-effects estimator has the additional benefit that, in contrast to using within-firm variation only, using also between-firm variation in our static panel-data model means that lagged effects on profit from renewable energy use are not neglected. This could be relevant when, for instance, reputation improvements from renewable energy use, and therefore the ability to charge higher prices, do not fully materialize instantly but take some time. The drawback of the random-effects model is that, because c is not explicitly modeled, unbiasedness of the estimates relies on the assumption that c is uncorrelated with firm profitability and the independent variables. We have tested for this assumption using the test proposed by Wooldridge (2010).[19] This test fails to reject that the firm-specific effect is uncorrelated with the other independent variables, providing support for the appropriateness of applying a random-effects estimation procedure.

To test for the presence of a linear relationship between profit and renewable energy use, we estimate the model in Eq. (3) and test the hypothesis that $\beta_1 = 0$ against the alternative that $\beta_1 \neq 0$. To test for the presence of U-shaped relationship, we estimate Eq. (4) and apply the test proposed by Lind and Mehlum (2010). Their formal test provides the necessary and sufficient conditions for the presence of a (n) (inverse-)U shape. The test entails testing the null hypothesis that a monotone or inverse-U shape (U shape) is present versus the alternative that a U shape (inverse-U shape) is present. We refer to their paper for the details of the test procedure.

Cluster-robust standard errors are computed because the autocorrelation test as proposed by Wooldridge (2010) indicates the presence of autocorrelation. In addition, from residual plots, it appears as if the predicted values become less accurate when the predicted value becomes larger, i.e. the models seem to suffer from heteroskedasticity. The standard errors are clustered at the level of the sub-sector based on the ICB classification (104 clusters).

5. Results and discussion

5.1. Results

Table 3 reports the estimation results. The estimated coefficient for renewable energy use is interpreted as the change in profit in US$ per MWh-change in renewable energy use. The first two columns report the results of a reduced model with only renewable energy as independent variable. The estimated coefficients for renewable energy use are negative, but not statistically significant.

The third and fourth column report our main results based on estimating Eq. (3) with a within-estimation and random-effects estimation procedure, respectively. By controlling for the other key variables, the interpretation of the estimated coefficient for renewable energy moves in the direction of a causal effect.[20] The estimated coefficient for renewable energy use in both models are negative and highly non-significant ($p=0.554$ in the fixed-effects and $p=0.938$ in the random-effects model). The key point estimates for the coefficient of renewable energy use are −10.78 from the fixed-effects model, and − 0.77 from the random-effects model. Taken at face value, the first coefficient suggests a negative effect on profit of €11 per MWh increase in *RE* use within a firm, and the second coefficient suggest an effect on profit of almost zero per MWh increase in *RE* use.[21] However, considering the respective 95% confidence intervals of [−46.67, 25.21] and [−20.32, 18.77], these key coefficients are not estimated with a high degree of

[19] In this case, the test of Wooldridge (2010) is more appropriate than the more conventionally applied Hausman test because the latter cannot accommodate the model's year-sector interactions and is not valid when the model suffers from heteroskedasticity.

[20] In our discussion of potential caveats in the conclusion, we particularly consider the threat that reverse causality poses to interpreting the coefficient of renewable energy as causal effect.

[21] It depends on the perspective whether €11 sacrifice in profit per MWh should be considered as substantial. Compared to the wholesale price of electricity (approximately €45/MWh in the past decade in Europe) or the certificate price (ranging from €2–€8 in Europe in 2018), this appears substantial. Considering the mean firm in the sample, however, this result translates to a decrease in profit of €11/MWh × 1432GWh = €15.5 mln on a total profit of €1132 mln.

Table 3
Estimation results. Dependent variable: net income (x1000 US$).

	Key var. only		Linear specification		Quadratic specification	
	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects
Renewable energy use (GWh)	−12.90	−8.20	−10.78	−0.77	−100.75	9.55
	(0.373)	(0.323)	(0.554)	(0.938)	(0.287)	(0.751)
(Renewable energy use)^2					0.001	−0.0001
					(0.294)	(0.620)
Assets (mln US$)			15.45*	6.05***	15.57*	6.05***
			(0.089)	(0.000)	(0.088)	(0.000)
Labor (fte)			−4.51	10.74***	−4.26	10.72***
			(0.625)	(0.000)	(0.644)	(0.000)
Total energy use (GWh)			0.58	3.92*	2.45	3.69
			(0.953)	(0.076)	(0.808)	(0.119)
Constant	1,293,553***	1,187,219***	737,110	935,284***	184,756	939,322***
	(0.000)	(0.000)	(0.276)	(0.000)	(0.785)	(0.000)
Pseudo R^2	0.0001	0.0002	0.23	0.32	0.23	0.32
No. of observations	2700	2700	2554	2554	2554	2554
No. of firms	972	972	911	911	911	911
Year-sector dummies+	No	No	Yes	Yes	Yes	Yes

P-value in parentheses. * $p < 0.1$, *** $p < 0.001$. + year-sector dummies are equal to one for firm *i* in year *t* if the firm belongs to sector *s* and zero otherwise.

precision. Unfortunately, with the sample at hand, the true effect is too small to detect.

In comparison with the meta-analytic results of e.g. Margolis, Elfenbein, and Walsh (2009) and Dixon-Fowler, Slater, Johnson, Ellstrand, and Romi (2013), the negative and non-significant coefficients do not provide support for the positive relationship between profit and renewable energy use. Instead, the absence of a statistically significant effect of renewable energy use on profit and the point estimate from the random-effects model provide support for a non-existent impact of renewable energy use on profit. This is in line with the predicted relationship based on the adopted product-differentiation framework with profit-maximizing firms. We do not find evidence for a 'win-win' in the form of a better environment and higher firm profit. The negative coefficient from the fixed-effects estimation could be interpreted as support for the notion that firms are sacrificing profit in favor of renewable energy use, although it is not statistically significantly different from zero. In addition, the lower coefficient estimated with the fixed-effects estimator, as compared to the random-effects estimator, may be partly explained by the existence of lagged positive effects of renewable energy use on revenue.

Columns five and six of Table 3 report the estimation results for the quadratic model in Eq. (4) using a fixed-effects and random-effects estimator, respectively. In the fixed-effects model, the estimated coefficients for renewable energy and its square have the required signs for a U-shaped relationship with profit, but are not statistically significant. In addition, the formal test for a U shape fails to reject the null-hypothesis at conventional significance thresholds (*p*-value 0.151). In contrast, in the random-effects model, the estimated coefficients point to a potential inverse-U-shaped relationship. However, both the statistical non-significance of the coefficients as well rejection by the formal test (p-value 0.376) do not provide evidence for the presence of an inverse-U shape. These results do not corroborate the U-shaped relationship between CSR and profit that Barnett and Salomon (2012) find.

With respect to the other variables, conform expectation, the coefficients for assets, labor and total energy use are positive and significant in the random-effects model. In the fixed-effects model, the coefficient for assets is conform expectation. However, the coefficient for labor is negative and not statistically significant and the coefficient for total energy use is positive and not statistically significant. While we expect positive coefficients for all three productive inputs, we may not be able to statistically detect these simultaneously in the fixed-effects model when the usage of the three productive inputs within a firm is strongly correlated over time. This is less problematic in the random-

Table 4
Robustness-estimation results. Dependent variable: net income (x1000 US$).

	Industry analysis		Continent analysis	
	Fixed effects	Random effects	Fixed effects	Random effects
Renewable-energy use interactions				
Energy & utilities sector	−2.57	−20.52		
	(0.654)	(0.118)		
Basic materials sector	−143.81	−4.75		
	(0.168)	(0.625)		
Industrial sector	262.55***	−64.68		
	(0.000)	(0.506)		
Consumer goods sector	−70.48	−46.70*		
	(0.22)	(0.068)		
Health care sector	−6137.53	1081.5		
	(0.299)	(0.100)		
Consumer services sector	205.22	−31.93		
	(0.676)	(0.898)		
Telecommunications sector	8591.37	643.53		
	(0.501)	(0.230)		
Financial sector	−38.85	28.12		
	(0.168)	(0.397)		
Technology sector	−74.84	3865.06***		
	(0.888)	(0.001)		
North-America			−98.81	10.31
			(0.316)	(0.622)
South-America			−94.09	−23.07
			(0.317)	(0.223)
Europe			0.69	−0.777
			(0.919)	(0.944)
Africa			−283.17	−6.87
			(0.24)	(0.699)
Asia			20.93	−14.99*
			(0.653)	(0.09)
Oceania			326.66***	34.39
			(0.000)	(0.302)
Assets	14.38	5.19***	14.32	5.33***
	(0.107)	(0.000)	(0.104)	(0.000)
Labor	−3.83	9.99***	−4.21	10.7***
	(0.679)	(0.000)	(0.647)	(0.000)
Total energy use	−3.18	4.49**	−9.3**	3.68**
	(0.581)	(0.015)	(0.01)	(0.025)
Constant	759,132	245,094	944,403	245,704
	(0.301)	(0.107)	(0.195)	(0.118)
Pseudo R^2	0.08	0.33	0.08	0.25
No. of observations	2554	2554	2554	2554
No. of firms	911	911	911	911
Year-sector dummies+	Yes	Yes	Yes	Yes

P-value in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. + year-sector dummies are equal to one for firm *i* in year *t* if the firm belongs to sector *s* and zero otherwise.

effects model because there is considerably more variation in the three productive inputs between firms than within firms (see Table 2). The estimated coefficients for the firm and year-sector fixed effects are not reported to facilitate readability and because they are of limited interest.

5.2. Exploring sectoral and geographical patterns

Given the large degree of heterogeneity in industry and geography across firms in the sample, this subsection investigates potential differences between industries and continents in the renewable energy use-profit association. To that end, we estimate models based on Eq. (3) that include interactions between industry and renewable energy use, and interactions between continent and renewable energy use. Table 4 reports the results of these estimations.

The first and second column of Table 4 report the results of the exploratory model with interactions between renewable energy use and industries, estimated with a fixed-effects and random-effects model, respectively. The following industries are included (classified on the basis of the ICB industries): energy & utilities, industrials, health care, telecommunications, consumer services, consumer goods, financials, and technology. Both models do not appear to suggest a large degree of heterogeneity between industries in the profit-renewable energy link, considering that most of the industry-specific coefficients for renewable energy use are not statistically significant. In the fixed-effects model, the only industry that has a statistically significant coefficient is the industrials sector, which has a positive coefficient. In contrast, in the random-effects model, we estimate a negative and statistically significant coefficient for the consumer goods sector, and a positive and statistically significant coefficient for the technology sector. Principally, the adopted theoretical framework in this paper and the resulting prediction that the effect of renewable energy use on profit is neutral are generic and apply (ceteris paribus) to all industries. We have not further analyzed these results, and providing explanations would be speculative.

Columns three and four of Table 4 report the results of the exploratory model with interactions between renewable energy use and continents, estimated with a fixed-effects and random effects model, respectively. From both models, we do not find large differences in the profit-renewable energy use association between continents, given that five out of six continent-specific coefficients are not statistically significant. The estimates in the fixed-effects model suggests that renewable energy use is only associated to a (positive) change in profit for Oceanian firms. In contrast, in the random-effects model, we estimate a statistically significant, negative coefficient for Asian firms.

6. Conclusion

Firms buy renewable energy at premiums and typically report environmental concern as motivation to do so. The empirical environmental CSR literature suggests that there even exists a ‘win-win’ from this type of firm behavior: more environmental CSR is associated with higher profit levels.

From a microeconomic perspective, however, higher profit from renewable energy use in particular, and environmental CSR in general, is typically not expected. On the one hand, firms may be able to differentiate themselves from competitors by using renewable energy and thereby charge higher prices. On the other hand, competition for those high-WTP consumers drives down prices towards the level of marginal costs. In addition, if we assume that the objective of the firm is to maximize profit, there is no scope for renewable energy use at the expense of profit. Therefore, in this profit-maximization framework, we expect that there is no effect from renewable energy use on profit.

This paper has analyzed the relationship between renewable energy use and firm profit. In particular, we have tested the prediction that there is no impact of renewable energy use on firm profit, using panel data for 920 firms from various regions and sectors over the period 2014–2018. In this panel, also firms that use no or hardly any renewable energy are strongly represented in the sample.

The results suggest that there is no impact from renewable energy use on profit. The interpretation of this results is twofold. Firstly, our results do not imply that a ‘win-win’ relationship between renewable energy use and profit exists. In other words, promoting social goals (a better environment) does not appear to be associated with higher profit. This is different from the meta-analytic results of the environmental CSR literature, which have established such a ‘win-win’ relationship. Secondly, the results also appear to imply that firms are not sacrificing profit when they use renewable energy, which could have been an indication for a positive willingness to pay for the environment by firms. These findings are in line with the expected relationship between renewable energy use and profit from the adopted framework of product-differentiation by profit-maximizing firms. However, in one model, we estimate a coefficient that is statistically not significant but, in terms of effect size, relatively close to the price of (European) RECs. Therefore, we recommend further research to verify this paper's findings.

The results appear to indicate that firms do not have objectives beyond maximizing profit, and that firms are only willing to contribute to climate change mitigation through the purchase of renewable energy when this contributes to the profit-maximization objective as well. For government policy, this would imply that policies should affect firms' financial incentives in order to induce changes in behavior. This can be done, for instance, by affecting revenues (e.g. reducing information asymmetry in markets for green types which may raise consumer WTP) or costs (e.g. by introducing taxes on polluting inputs or subsidies for non-polluting alternatives).

This paper's main contribution is that it is the first to explicitly study the relationship between renewable energy use and profit. In addition, in relation to the broader environmental CSR literature, this paper uses a specific and concrete measure of environmental CSR in the form of renewable energy use, rather than an indicator variable of which it is not clear to what extent it represents actual environmental performance.

Several caveats of the current study need to be mentioned. First, on the basis of foundations of the microeconomic theory of the firm, such as profit maximization and product differentiation, this paper theorizes and empirically postulates that causality runs from renewable energy use to profit. We have not controlled for a potentially reverse relationship in which profit causes changes in renewable energy use, as this is highly complicated by the unavailability of data for truly exogenous instruments for renewable energy use. A reverse causal relationship might result from adopting other theoretical perspectives (e.g. agency theory). While the existing empirical evidence currently does not appear to support a causal relationship from CSR to profit (Kang, Germann, and Grewal, 2016; Scholtens, 2008), if the true relationship is of this kind, this paper's estimation results may suffer from an endogeneity bias. Secondly, considering the considerable standard errors, the key regression coefficients are not highly precise. As a result, we cannot conclusively distinguish between an effect of renewable energy use on profit that is zero or relatively small. Thirdly, the empirical analysis uses net income as measure for profit. This is a measure of accounting profit, whereas the theory concerns the relationship between economic profit and renewable energy use. To verify the findings of this paper and because firms increasingly play an important contribution in societies' efforts to mitigate climate change, further research regarding the link between firms' environmental contributions and financial objectives is required.

Credit author statement

Joint work by Daan Hulshof and Machiel Mulder.

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Appendix A

Table A.1
Estimation results of alternative specifications including R&D expenditure (first two columns) and debt (last two columns) as control variables.

	Model incl. R&D exp.		Model incl. Debt	
	Fixed effects	Random effects	Fixed effects	Random effects
RE	−14.83	0.52	−10.39	−0.81
	(0.468)	(0.949)	(0.877)	(0.935)
K	56.79**	16.95*	20.03**	6.13***
	(0.048)	(0.088)	(0.03)	(0.000)
L	−15.30	1.90	−4.01	10.74***
	(0.193)	(0.505)	(0.955)	(0.000)
TE	2.58	1.15	0.23	3.94*
	(0.653)	(0.751)	(0.981)	(0.079)
R&D	−55.92	995.05***		
	(0.907)	(0.001)		
Debt			−22.17*	−0.35
			(0.081)	(0.951)
Constant	790,027.3	705,224.6***	871,787.2	936,025.5***
	(0.172)	(0.000)	(0.208)	(0.000)
Pseudo R^2	0.28	0.41	0.24	0.32
No. of obs.	2098	2098	2554	2554
No. of firms	765	765	911	911
Year-sector dummies+	Yes	Yes	Yes	Yes

P-value in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
+ year-sector dummies are equal to one for firm *i* in year *t* if the firm belongs to sector *s* and zero otherwise.

Appendix B

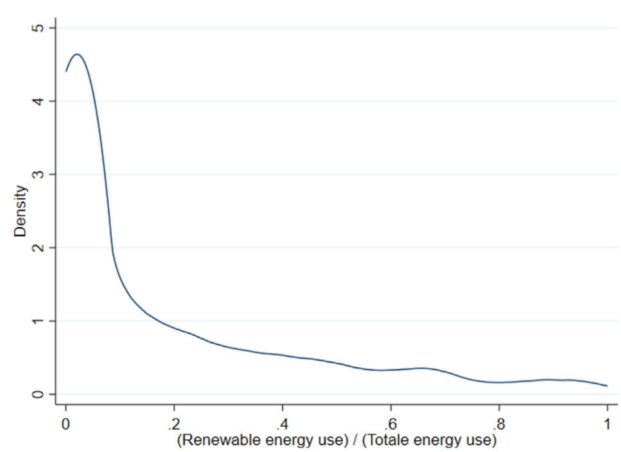

Fig. 2. Kernel density plot of the share of renewable energy use in total energy use of the firm-years in the sample

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