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Abstract

Finland's 2011 energy tax reform increased excise taxes on energy. The tax increase raised concerns about competitiveness of the manufacturing sector, and in the beginning of 2012 a pre-existing tax exemption to manufacturing was extended to a larger set of firms. The extension increased the number of firms eligible for energy tax refunds from about ten to over 140. At the same time, the tax refunds increased from just under EUR 10 million to over EUR 200 million.

This study evaluates the effects of the energy tax refunds on the economic and environmental performance of the manufacturing firms that became tax exempt in 2011-2012. We compare detailed information on the newly exempt and non-exempt plants' economic outcomes and energy use to estimate the impact of the energy tax exemption on plants' economic performance and energy efficiency.

In the period 2012-2016 the refunds were on average 1 percent of the total expenses of the firms that have been refund recipients since 2011-2012. Comparison of exempt and non-exempt plants' energy intensities, if measured by the ratio of electricity use to total expenses, suggests that the energy tax refund does not sort out particularly energy intensive manufacturing. That is, plants can have similar energy intensities but receive different tax treatment.

The results on the impact of the energy tax refund on the economic performance of manufacturing plants are most compatible with no important effect on revenue, value added, wages, employees or total energy use, and a negative impact on gross output and energy efficiency.

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Tiivistelmä

Vuoden 2011 energiaverouudistus korotti energian valmisteveroja. Veronkorotus herätti huolen teollisuuden kilpailukyvystä, ja vuoden 2012 alusta laajennettiin jo aiemmin käytössä ollutta teollisuuden energiaverojen palautusta aikaisempaa suurempaan joukkoon yrityksiä. Uudistus moninkertaisti energiaveron palautuksiin oikeutettujen yritysten määrän noin kymmenestä yli 140 yritykseen. Maksettujen palautusten arvo kasvoi samalla vajaasta 10 miljoonasta eurosta yli 200 miljoonaan euroon.

Tutkimus vertaa vuosina 2011-2012 palautusten piiriin tulleiden ja edelleen ilman palautuksia jääneiden tuotantolaitosten taloudellisia tuloksia ja energian käyttöä ja arvioi energiaverojen palautusten vaikutuksia tuotantolaitosten taloudelliseen menestykseen ja energiatehokkuuteen.

Energiaverojen palautusten osuus palautusten piiriin tulleiden yritysten kustannuksista oli keskimäärin yksi prosentti ajanjaksolla 2012-2016. Jos energiaintensiivisyyttä mitataan sähkön kulutuksella suhteessa kokonaiskustannuksiin, palautusten piiriin tulleet tuotantolaitokset eivät keskimäärin olleet erityisen energiaintensiivisiä verrattuna ilman palautuksia jääneisiin tuotantolaitoksiin.

Tutkimuksen tulokset tukevat eniten johtopäätöstä, että veronpalautuksilla ei ole ollut vaikutusta vuosista 2011–2012 alkaen palautusten piiriin kuuluneiden tuotantolaitosten liikevaihdon, arvonlisäyksen, palkkojen, työllisten määrän tai energian käytön kehitykseen, ja että niillä on ollut negatiivinen vaikutus tuotannon arvon ja energiatehokkuuden kehitykseen.

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Referat

Till följd av energiskattereformen 2011 höjdes punktskatten på energi. Skattehöjningen väckte oro för industrins konkurrenskraft. Därför utvidgades återbäringen av energiskatt till industrin i början av 2012 till en allt större del av företagen. Genom reformen flerdubblades antalet företag som är berättigade till återbäring av energiskatt, från cirka tio företag till över 140. Samtidigt ökade beloppet på återbäringarna från knappt under 10 miljoner euro till över 200 miljoner euro.

Utredningen jämför de ekonomiska resultaten och energiförbrukningen för produktionsanläggningar som blev berättigade till återbäring 2011–2012 respektive anläggningar som fortfarande inte beviljats återbäring. Dessutom bedöms inverkan av återbäringarna av energiskatt på produktionsanläggningarnas ekonomiska framgång och energieffektiviteten.

Under tidsperioden 2012–2016 utgjorde återbäringarna av energiskatten i snitt en procent av kostnaderna i de företag som beviljats återbäring. Om energiintensiteten mäts utgående från hur mycket elförbrukningen utgör av de totala kostnaderna, var de produktionsanläggningar som fick återbäring inte särskilt energiintensiva jämfört med de anläggningar som inte fick återbäring.

Resultaten av utredningen stöder främst slutsatsen om att skatteåterbäringarna inte från och med 2011–2012 har haft någon inverkan på hur de berättigade produktionsanläggningarnas omsättning, förädlingsvärde, löner, antal sysselsatta eller energiförbrukning har utvecklats, och att skatteåterbäringarna har haft en negativ inverkan på hur produktionens värde och energieffektiviteten har utvecklats.

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Vuoden 2011 energiaverouudistus korotti energian valmisteveroja. Samalla polttoaineiden verotus sidottiin osittain poltosta aiheutuviin hiilidioksidipäästöihin. Veronkorotus herätti huolen teollisuuden kustannuksista, ja vuoden 2012 alusta laajennettiin vuodesta 1998 käytössä ollutta teollisuuden energiaverojen palautusta aikaisempaa suurempaan joukkoon yrityksiä. Uudistus moninkertaisti energiaveron palautuksiin oikeutettujen yritysten määrän noin kymmenestä yli 140 yritykseen. Maksettujen palautusten arvo kasvoi samalla vajaasta 10 miljoonasta eurosta yli 200 miljoonaan euroon vuodessa.

Energiaverojen palautusten tavoitteena on tukea yritysten kykyä työllistää, tehdä investointeja ja kasvaa sekä ylläpitää Suomen kansainvälistä kilpailukykyä. Tämä tutkimus pyrkii arvioimaan energiaverojen palautusten vaikutuksia vertaamalla vuosina 2011–2012 palautusten piiriin tulleiden ja ilman palautuksia jääneiden tuotantolaitosten kilpailukykyä, työllisten määrää ja energian käyttöä. Kilpailukyvyllä tarkoitetaan tässä sitä, kuinka hyvin tuotantolaitokset ovat menestyneet tuotannon määrällä, liikevaihdolla ja arvonlisäyksellä mitattuna. Tutkimus hyödyntää Verohallinnon tietoja energiaverojen palautuksista ja Tilastokeskuksen Teollisuuden toimipaikkapaneelin tietoja tuotantolaitosten tuotoksesta, liikevaihdosta, arvonlisäyksestä sekä lukuisista taustamuuttujista. Lisäksi tutkimus käyttää Tilastokeskuksen Teollisuuden energiankäyttö -tilaston tietoja tuotantolaitosten energiapanoksista. Aineistoa on käytettävissä vuosilta 2007–2016.

Veronpalautuksia saaneiden yritysten tuotantolaitoksille muodostettiin verrokkiryhmä etsimällä kullekin veronpalautusten piiriin 2011–2012 tulleelle tuotantolaitokselle taustaominaisuuksiltaan mahdollisimman samankaltaiset verrokit veronpalautuksia vaille jääneistä tuotantolaitoksista. Verrokit muodostettiin saman toimialan tuotantolaitoksista. Toimialarajauksen lisäksi kriteereinä verrokkien muodostamiselle käytettiin tuotantolaitoksen energian käyttöä sekä sähkönkulutuksen suhdetta kokonaisenergian käyttöön verouudistusta edeltävinä vuosina 2007–2010. Koska palautusten piiriin vuosina 2011–2012 tulleet toimipaikat ovat yleisesti ottaen suurempia kuin ilman palautuksia jääneet, ryhmien välille jää eroja mittakaavaan sidoksissa olevissa taustaominaisuuksissa. Mittakaavaeroista mahdollisesti syntyvän harhan välttämiseksi vertailussa arvioitiin eroja tuotantolaitosten tulosten, työllisten määrän ja energiatehokkuuden kehityksessä yli ajan, ei tasoeroja näiden muuttujien välillä yksittäisenä tarkasteluvuonna.

Energiaverojen palautusten osuus vuosina 2011-2012 palautusten piiriin tulleiden yritysten kustannuksista oli keskimäärin yksi prosentti ajanjaksolla 2012-2016. Jos energiaintensiivisyyttä mitataan sähkön kulutuksella suhteessa kokonaiskustannuksiin, palautusten piiriin tulleet tuotantolaitokset eivät olleet erityisen energiaintensiivisiä verrattuna ilman palautuksia jääneisiin tuotantolaitoksiin. Vuosina 2011–2012 energiaverojen palautusten piiriin tulleiden laitosten tuotannon arvon kehittyi vuosien 2010 ja 2016 välillä heikommin kuin ilman palautuksia jääneiden laitosten. Samoin tuotannon energiatehokkuuden kehitys jäi vuosina 2011–2012 energiaverojen palautusten piiriin tulleissa laitoksissa heikommaksi kuin ilman palautuksia jääneissä laitoksissa.

Tutkimuksen tulokset tukevat eniten johtopäätöstä, että veronpalautuksilla ei ole ollut vaikutusta vuosista 2011–2012 alkaen palautusten piiriin kuuluneiden tuotantolaitosten liikevaihdon, arvonlisäyksen, palkkojen, työllisten määrän tai energian käytön kehitykseen, ja että niillä oli negatiivinen vaikutus tuotannon arvon ja energiatehokkuuden kehitykseen.

1 Introduction

Along with increasing policy effort to mitigate climate change, the impact of climate policy on firm performance has become a heated topic in the political debate. Especially in countries where climate policy has tightened significantly relative to competitors, concerns have been raised about adverse effects of unilateral climate policies on manufacturing firm performance. In theory, the effect of environmental policy on firm performance could go either way. Other things equal, environmental regulation increases firms' costs and thus reduces their cost competeveness. If firms compete in prices, the disadvantage relative to firms operating in locations with laxer environmental policies may harm regulated firms' sales and reduce their production, and eventually employment. Firms may also be pushed to shift production capacity to locations with laxer environmental policies with the consequence of pollution leakage, as predicted by the pollution haven hypothesis (Levinson and Taylor 2008). An alternative view is expressed in the Porter hypothesis, which states that environmental regulation may enhance the competitiveness of regulated firms, through pushing them to engage in environmentally friendly innovation and technology adoption that would not have happened in the absence of policy (Porter 1991). Both in Finland and in the EU many policy makers have expressed the concern that EU's ambitious climate policy will shift production to countries with laxer climate policy, while others have promoted the vision that low-carbon innovation will be a driver of competitive advantage and economic growth.

Given the two theories with opposite predictions, the effect of environmental policy on manufacturing firm performance remains an empirical question. The environmental policy tools used in practice have also been changing. Regulators are increasingly adopting market-based instruments to curtail emissions. The shift from command and control approaches towards market-based instruments raises questions about how well these instruments work in terms of their environmental objectives. Causal evidence on both the effect of environmental policies on manufacturing firm performance and on what market-based policies deliver in terms of emission reductions is still sparse, in particular in the context of climate policy.

This paper seeks to evaluate the effect of an energy tax exemption on the economic and environmental performance of manufacturing firms. We examine these two issues in the context of Finland's "green" energy tax reform that substantially increased the excise taxes on energy inputs, with the aim of promoting energy efficiency and reducing CO_2-emissions. The preparation of the tax reform was accompanied by controversy over the predicted effects on manufacturing firm competitiveness, with the consequence that firms above a certain energy tax threshold were granted exemption from energy taxes. While firms below the threshold pay energy taxes in full, firms above the threshold are refunded up to 85 percent of their energy taxes. Exempt and non-exempt firms, and in particular plants within these firms, can be otherwise very similar. The exemption rule is important from a statistical analysis point of view in that it allows us to compare plants that operate in the same manufacturing sectors and have otherwise similar history, but have been subject to different effective tax rates since the tax reform.

In order to evaluate the causal impact of the energy tax exemption on manufacturing firms' economic and environmental performance, we use a detailed data set on the universe of Finnish manufacturing plants, combined with comprehensive plant-level information on energy consumption. We exploit the detailed information to estimate the impact of the energy tax exemption by combining a difference-in-differences approach with semiparametric matching techniques.

Overall the results presented here are most compatible with no important effect of the energy tax refund on employees, wages or energy use on average, and, if anything, a negative impact on gross output and energy efficiency.

2 Literature review

Literature on international trade generally groups the main determinants of firms' international competitiveness into three broad categories: firm level factors, sector level factors, and country/region specific factors. Firm level factors have generally been found to be the most important determinants of both domestic and international competitiveness (see e.g. Goddard et al. 2005, Goddard et al. 2009, Brakman et al. 2009, Wagner 2012). Hottman et al. (2016) and Crozet et al. (2012) have identified perceived product and firm quality (firm appeal) as the most important firm-level driver of competitiveness. Hottman et al. (2016) analyzed the sales and prices of millions of products in the United States in years 2004-2001. They found that product quality accounted for 50-75 percent of firm-level success factors and 90 percent of sales increases. Prices and costs instead explained only 25 percent of the general success of a firm, and for the majority of products changes in costs had no effect on sales development.

There are only few studies on the effect of energy or carbon taxes on the competitiveness of manufacturing firms. Arlinghaus (2015) provides a fairly recent literature review and concludes that carbon taxes or EU emissions trading have had little impact on competitiveness at the firm, sector or country level. According to Arlinghaus, carbon pricing has had some success in reducing firms' energy intensity and carbon emissions, while tax relief to energy-intensive industries has not affected competitiveness indicators in manufacturing.

Finland's energy tax refund system has previously been studied by Harju et al. (2016). Harju et al. analyzed the tax exemption at firm-level and focused on the association between tax refunds and firm performance. They found no evidence of robust, statistically significant association between energy tax refunds and measures of firm performance. We complement the work in Harju et al. (2016) by analyzing more detailed plant-level data and a time period five years after the reform, which adds a more long-term view as plants will have had more time to adjust to the changes in the tax schedule. Furthermore, we use an identification strategy that allows for estimating the causal impact of the tax exemption policy. We also examine effects on plants' energy use and energy efficiency, not included in the analysis by Harju et al. (2016).

Further studies closely related to the present paper have examined the effects of similar tax exemptions on manufacturing firm performance in other EU countries. Gerster and Lamp (2018) analyzed a tax exemption to large manufacturing plants in Germany. They examined a change in the tax schedule in 2012 that reduced the threshold of electricity use above which plants are exempt. Newly exempt plants were found to increase their energy use some but their sales did not increase. The number of employees in newly exempt plants decreased some, which Gerster and Lamp suggest could be because they substituted bought electricity for generation on site. Flues and Lutz (2015) studied the effects of German electricity taxation prior to EU Emissions Trading, in years 1999-2005. They used a regression discontinuity approach and exploited a threshold in the electricity tax system which assigned a lower tax rate to industries with high electricity use. They found no effect of the tax relief on firm revenue, exports, value added, investments or employment. Martin et al. (2014) analyzed the effects of energy taxes in the United Kingdom, also prior to EU Emissions Trading. The United Kingdom granted energy-intensive manufacturing firms an 80 percent concession in their energy taxes if they committed to voluntary agreements to reduce their energy use or carbon emissions. The energy use or carbon emission targets, however, were not very ambitious. Martin et al. used a differences-in-differences approach and instrumental variables to study the effects of the tax relief. They found that paying the full tax had no effect on production, productivity or employment but that it reduced firm energy intensity notably relative to firms that obtained the tax relief.

Anger and Oberndorfer (2008) examined the effect of the free allocation of emissions permits to German firms participating in the EU Emissions Trading System. While the research design differs from those in Flues and Lutz (2015) and Martin et al. (2014), the initial free allocation of emission permits can be perceived as support to energy-intensive manufacturing, similar to tax relief. Anger and Oberndorfer found no difference in the profitability or employment in manufacturing firms that would have been attributable to a firm having been overallocated free emission permits or having to buy emissions permits from the market in 2005.[1]

A closely related literature studies the effects of EU emissions trading on manufacturing firm performance and CO_2-emissions. Dechezleprêtre et al. (2018) used data for all EU countries, for altogether 1800 firms that participate in emissions trading. They compared regulated firms to firms that are otherwise very similar but not regulated. They found no evidence of negative effects of EU emissions trading on firm performance. Regulated firms' revenue and fixed assets were instead found to have increased, perhaps due to investments by regulated firms in cleaner and at the same time more efficient technologies.

Similar conclusions can be drawn based on studies for individual EU countries. In France, EU emissions trading increased investment in regulated firms, without overall impacts on employment or value added (Wagner, Muûls, Martin and Colmer 2014). Results were similar for Germany (Petrick and Wagner 2014). In Norway, emissions trading appears to have increased productivity and value added some, although the result may be due to generous free allocation of emissions permits (Klemetsen, Rosendahl and

[1] The prices of emission permits in the EU ETS were substantially higher in 2005, prior to the first emissions reports being published in April 2006, than in 2006-2007. Once the first emissions reports came out, prices collapsed, reaching zero towards the end of the first EU ETS phase in 2005-2007.

Jakobsen 2016). For Lithuania, no effect was found on firm performance (Jaraite and Di Maria 2016).

Finally, Marin and Vona (2017) utilized a detailed data set on manufacturing plant energy expenditure and energy use, which allowed them to calculate plant-specific energy prices. They found energy prices to have a small negative impact on employment and productivity: a 10 percent increase in energy prices decreased employment by 2,6 percent and productivity by 1,1 percent.

3 Institutional setting

3.1 Finland's 2011 energy tax reform and change in energy tax exemption rule

Finland's 2011 energy tax reform markedly increased the excise tax rates on coal, natural gas, oil and electricity.[2] As a follow-up of the reform, a pre-existing tax exemption for large energy-intensive firms was expanded to a substantially larger set of firms.[3] The stated motivation for the tax exemption was securing the international competitiveness of Finland's energy-intensive export industries, by attenuating the energy cost increase brought along by the tax increase.[4]

The exemption rule is based on firms' energy tax payments relative to their value added, a measure of energy intensity. The energy taxes are excise taxes, and energy tax payments are thus determined based on the quantities of energy inputs purchased. If a firm's taxes on electricity and fuels within an accounting period exceeded 0,5 percent of its value added, it will be refunded 85 percent of difference, subject to a 50 000 euro deductible. Formally, the tax exemption rule is

*Refund = (Energy taxes paid - value added*0,005)*0,85 - 50 000 (eur).* [5]

Energy taxes include excise taxes on electricity, district heat and process steam production, and carbon and energy content based taxes on heating fuels. Value added comprises operating profit (- loss), write-offs, depreciation, and labor costs (total of wages and social benefits). Firms apply for the tax refund annually based on certified accounts.

Through 2011, the exemption rule entitled only firms whose energy tax payments exceeded 3,7 percent of value added to be granted the exemption. The tax legislation was changed in December 2011 to lower the threshold from 3,7 to 0,5 percent from January

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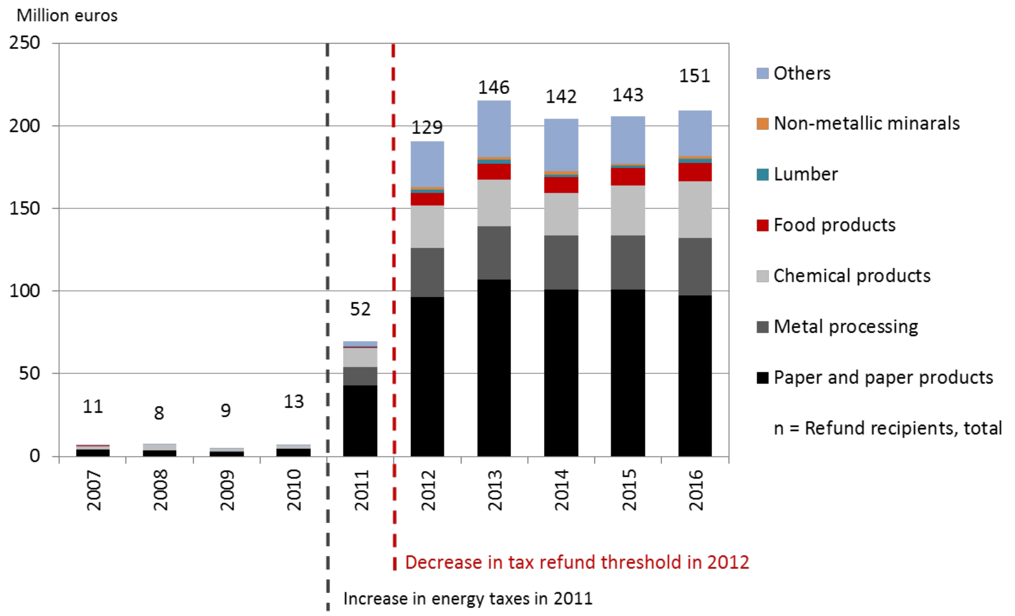
[2] The energy tax reform changed both the structure of energy taxation and energy tax rates so that the excise taxes on fuels comprised of an energy content component and a CO_2 component. The CO_2 tax rate used in computing the excise tax on different energy products increased from 20 EUR/tCO_2 to 30 EUR/tCO_2.
[3] The tax exemption was first implemented in September 1998.
[4] HE 129/2011 v 295783 - Proposal by the Government to the Parliament to amend Section 8a of the Act on Excise Duty on Electricity and Certain Fuels. In Finnish, HE 129/2011 vp 295783 - Hallituksen esitys Eduskunnalle laiksi sähkön ja eräiden polttoaineiden valmisteverosta annetun lain 8 a §:n muuttamisesta.
[5] A negative value added replaced by zero in the calculation.

2012 onwards, following an outcry from the industry after the energy tax rates were increased in the beginning of 2011. The changes in the energy tax rates and exemption threshold together brought along a notable increase in both the total amount of the tax refunds and the number of recipients. When only 13 firms received a refund in 2011, the number of recipients increased to more than 140 after 2012. The total amount of taxes refunded increased from 7 million euros to over 200 million euros a year.

Figure 3.1. summarizes the change in the number of firms receiving energy tax refunds (solid line), the amount of tax refunds paid from 2003 onwards, and the composition of the group of tax refund recipients in terms of the industrial sector. In terms of industries, paper manufacturing has received the largest proportion of the energy tax refunds, followed by chemical and plastic manufacturing and metals and minerals manufacturing.

Figure 3.1. The total amount of energy tax refunds and the number of refund recipient firms from 2003 to 2016.



Sources: Finnish Tax Administration and Customs Finland.

3.2 Hypothesized effects of the energy tax exemption

A natural starting point for evaluating the effects of the energy tax exemption is provided by the policy objectives stated when the energy tax exemption was extended in 2011. The stated policy objectives were as follows: promote the ability of energy intensive firms to employ, invest, and grow, as well as maintain Finland's international competitiveness.[6] The objectives were not clarified further in the legislative proposal. Competitiveness is an ambiguous term, so a discussion of the effects that we seek to measure is warranted before proceeding to our analysis.

In terms of a firm, competeveness would in general be interpreted as a strong market position and profitability above that of competitors. The mechanism through which one would expect the energy tax refund to affect firms' market position and performance is through a cost competitiveness channel. Other things equal, the energy tax exemption reduces the relative unit energy cost of the tax exempt firms relative to their competitors. If the firms produce goods that compete in prices, the lower unit energy cost should enable tax exempt firms to reduce their prices and increase their sales relative to their competitors. Even if the firms produce goods that are at least to some extent differentiated and hence do not compete entirely in prices, the lower unit energy cost could still result in both lower prices and increased sales. Increased sales in turn would be manifested as increased output, employment and, in the case of energy intensive industries, energy use.

Our data include three output measures that can be used as firm performance indicators: gross output, revenue and value added. The output measures are defined as follows. Gross output measures the value of a plant's total output. Revenue measures the sales of the plant's output. Gross output differs from revenue in that in addition to sales, it includes output used by the plant itself, deliveries to the owner firm's other plants, and changes in storage. Value added in turn measures the difference between the value of total output and production costs, excluding labor costs. We also observe the number of employees and energy use in each plant. We hypothesize that the effect of the unit energy cost reduction produced by the tax exemption would show as an increase in gross output, revenue, value added, employment and energy use.

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[6] HE 129/2011 v 295783 - Proposal by the Government to the Parliament to amend Section 8a of the Act on Excise Duty on Electricity and Certain Fuels. In Finnish, HE 129/2011 vp 295783 - Hallituksen esitys Eduskunnalle laiksi sähkön ja eräiden polttoaineiden valmisteverosta annetun lain 8 a §:n muuttamisesta.

It is also possible that the tax refunds will be in part passed through to compensation for other factors of production, such as worker wages, or routed to executives and shareholders. If increased sales led to increased wage growth, the cost competitiveness advantage provided by the energy tax exemption could be offset by increased labor costs. To shed on light whether such pass-through has occurred, we assess whether energy tax refunds have led to increased wage growth in exempt plants.

As cost competitiveness is jointly determined by the unit costs of inputs and firms' productivity, the effect of the energy tax exemption on productivity measures is also of interest in terms of long-term competitiveness. In the case of energy intensive industries, energy efficiency (output per unit of energy) is particularly relevant. Firms facing higher unit energy prices could, for example, invest more in energy efficiency improvements, which in turn would reduce the cost competitiveness gap – a one percent reduction in the unit cost of energy would be offset by a one percent increase in energy efficiency.

Table 3.1 shows the size of the energy tax refunds relative to the total expenses of the energy tax exempt firms in the main refund recipient industries. Overall, the refunds have corresponded to approximately 1 percent of the total expenses of the refund recipient firms. The size of the refunds relative to total expenses has been highest in food products, ranging from slightly under 1 to over 3 percent, followed by paper and paper products at slightly over 1 percent, and chemical products at slightly under 1 percent.

Table 3.1. Energy tax refunds relative to the total expenses for firms that started receiving energy tax refunds in 2011-2012

Industry	2012	2013	2014	2015	2016
Food products	3,11 %	0,94 %	1,00 %	1,34 %	1,45 %
Lumber	0,14 %	0,19 %	0,16 %	0,21 %	0,29 %
Paper and paper products	1,25 %	1,16 %	1,20 %	1,12 %	1,07 %
Chemical products	0,66 %	0,80 %	0,86 %	0,97 %	1,18 %
Non-metallic minarals	0,02 %	0,48 %	0,42 %	0,45 %	0,55 %
Metal processing	0,46 %	0,35 %	0,34 %	0,35 %	0,37 %
All industries	1,17 %	0,91 %	0,93 %	1,03 %	1,18 %

Source: Own calculations using data from Finnish Tax Administration and Statistics Finland Business Register. Notation ".." means that there were fewer than three firms in the cell and the results cannot be reported due to data confidentiality restrictions.

4 Research design

4.1 Difference-in-differences matching estimator

We seek to identify the average effect of energy tax exemption on plants within firms that qualified for the exemption as a consequence of the 2011-2012 energy tax reform. To identify this parameter, we adopt a difference-in-differences matching approach similar to the one used for example in Fowlie, Holland and Mansur (2012), Petrick and Wagner (2014), Wagner, Muûls, Martin and Colmer (2014) and Gerster and Lamp (2018). The approach exploits the longitudinal structure of our dataset and the rich information on plant characteristics, both in terms of economic variables and energy use.

In line with the potential outcome framework, let $Y_i(1)$ denote the outcome of plant *i* when the plant is energy tax refund recipient, and $Y_i(0)$ when the plant is not eligible for an energy tax refund. Let D_i denote the treatment indicator, and subscripts *t* and *t'* pre- and post-treatment periods, respectively. Let *X* denote a set of covariates. We seek to identify the average treatment effect on the treated (ATT):

$$\alpha_{ATT} = E[Y_{it'}(1) - Y_{it'}(0) \mid D_i = 1], \quad (1)$$

where *t'* refers to year following the 2011-2012 tax reform and α_{ATT} measures the average effect of the tax exemption on annual plant level outcome. The fundamental evaluation problem here is that outcome $Y_{it'}(0)$ is not observed for the treated plants. The matching approach constructs estimates of these counterfactual outcomes using outcomes observed for untreated plants that are observationally similar to the to the treated plant. The ATT can then be estimated from the sample equivalent of the expression

$$E[Y_{it'}(1) \mid X, D_i = 1] - E[Y_{it'}(0) \mid X, D_i = 0] \;, \quad (2)$$

assuming conditional independence between outcomes and treatment status, $(y_{it'}(0), y_{it'}(1)) \perp D \mid X$. Unfortunately, in light of the fact that eligibility for the energy tax exemption is defined by an energy tax payment threshold, the unconfoundness assumption appears too demanding for the policy context here.

However, the ATT can be identified under weaker assumptions by exploiting longitudinal information and focusing on differences-in-differences (DiD) outcomes. Heckman, Ichimura and Todd (1997) suggest estimating the ATT from the sample analogues of the population moments

$$D_{t',t}(\mathrm{X}) = \mathrm{E}\left[Y_{it'}(1) - Y_{it}(0) \mid X, D_i = 1\right] - \mathrm{E}\left[Y_{it'}(0) - Y_{it}(0) \mid X, D_i = 0\right] \ . \qquad (3)$$

To implement this, they suggest the following semiparametric conditional DiD matching estimator:

$$\widehat{\alpha_{ATT}} = \frac{1}{N_1} \sum_{j \in I_1} \left\{ \left(Y_{jt'}(1) - Y_{jt^0} \right) - \sum_{k \in I_0} w_{jk} \left(Y_{kt'}(0) - Y_{kt^0}(0) \right) \right\}. \qquad (4)$$

Here, N_1 is the number of plants in the treatment group of refund recipients, I_1 the set of refund recipients and I_0 the set of plants not receiving energy tax refunds. The refund recipients are indexed by *j* and the non-recipients by *k*. Plant *k* is given weight w_{jk} when constructing the counterfactual estimate for treated plant *j*. The weight determines the extent to which counterfactual observation *k* contributes to the estimated treatment effect. The more similar a control plant *k* is to the treated plant *j*, the greater weight w_{jk} it receives. The specific weighting procedure depends on the matching algorithm.

4.2 Identifying assumptions

Our identification strategy is based on the following identifying assumptions:

1. The matching estimator identifies the ATT under the assumption that

$$E\left[Y_{it'}(0) - Y_{it}(0) \middle| P(X), D = 1\right] = E\left[Y_{it'}(0) - Y_{it}(0) \middle| P(X), D = 0\right] \qquad (5)$$

   (Heckman, Ichimura and Todd 1998). In our application the assumption means that the counterfactual trends in the outcomes of the tax exempt plants do not systematically differ from those in the group of matched control plants. In other words, we assume that conditional on the matching variables the outcome variables of the exempt and non-exempt firms would have followed a parallel trend after the 2011 energy tax reform, had the exempt firms not become eligible for tax refunds.

2. A further identifying assumption is that matching is performed on a common support $X \in S\left(P(X) \middle| D = 1\right)$ where the distributions of the covariates in the treatment and control groups overlap.

3. Finally, in order to rule out spillovers and general equilibrium effects, it must also be the case the potential outcomes at one plant are independent of the treatment status of other plants. This assumption is generally referred to as the stable unit treatment value assumption.

   It is possible to test the common support assumption (2), whereas the parallel trends assumption (1) and stable unit treatment value assumption (3) are not directly testable. We will next introduce our data and matching algorithm, and then evaluate how plausible these assumptions are in light of descriptive statistics (Section 5.4) and indirect tests (Section 6).

   Note that control plants do not need to be exact matches for treated plants in terms of observable characteristics. The matching algorithm has to determine a tolerance limit for how different control plants can be from a treated plant and still be a match.

5 Data and matching algorithm

5.1 Data sources

Our principal dataset is the Longitudinal Database on Plants in Finnish Manufacturing (LDPM) panel from Statistics Finland. The LDPM panel starts from 1974 and comprises annual data from the universe of Finnish manufacturing plants that belong to firms with at least 20 employees. The dataset contains information on a wide range of economic variables such as revenue, value added, employment, wages, investment, total expenditure and the shares of electricity and other fuels in the total expenditure. The data are collected annually as part of a survey that compiles data for the Structural Business Statistics database of Statistics Finland. Firms are obliged to reply based on the Statistics Act (Act 280/04). We use LDPM data for the years 2007-2016.

Our other essential dataset is the Energy Use in Manufacturing database of Statistics Finland which starts from 2007 and provides establishment-level information on the use of electricity, heat and over 20 different fuel types. The data are collected through an annual survey that covers establishments in manufacturing and mining.[7] Again, firms are obliged to reply based on the Statistics Act (Act 280/04).

The complete list of energy tax refund recipient firms and refund sums for years 2007-2016 was obtained from the Finnish Tax Administration. The information was merged with the LPDM panel and energy use databases for years 2007-2016 by Statistics Finland on the basis of confidential firm identification numbers. The combined dataset contains information on establishment level economic outcomes, expenditure and energy use and firm level information on tax refunds for years 2007-2016.

5.2 Matching sample construction

The sample of plants that is used in each matching analysis is constructed as follows. From the overall combined dataset, we use plants that were in the data set in 2007 to 2010, the years before Finland's energy tax reform that our energy use data cover, and in at least one of the years 2015-2016. These plants are divided into treatment and comparison groups. The treatment group in the base case analysis includes plants that first qualified for the energy tax exemption in 2011 or 2012, and remained tax exempt through 2016. The comparison group only includes plants have never been tax exempt. That is,

[7] Establishments of ten or fewer employees are only included every fourth year.

we remove plants that were exempt from energy taxes already prior to the 2011 energy tax reform, and plants that first became exempt after the tax reform but did not qualify in all the years 2012-2016. These plants have a lower intensity of treatment overall than the plants that were always exempt once they first qualified for the exemption. Firms pay energy taxes on the fuel and electricity that they use in their production process and are only refunded taxes exceeding the threshold after the end of the accounting period. Firms form expectations about the energy tax refunds that they incorporate into their production and investment decisions. In case of firms that were eligible for the refund every year after the 2011 reform we proceed from the assumption that firms form rational expectations about their future energy tax refunds based on their previous energy taxes and refunds. Expectations regarding future tax refunds are less clear for plants that qualified in some years but did not in others. Future work should consider an alternative specification that includes these plants. Furthermore, we remove plants for which information is missing on any of the observational characteristics that are used in matching and regressions for the pre-reform year 2010. For the baseline results on treatment effect on the treated for the post-reform years 2015 to 2016, we use all possible observations, irrespective of whether some or all of the information might be missing for some of the other years 2012 to 2016.

5.3 Matching algorithm

The nonparametric matching estimator constructs the counterfactual outcome estimate for each treatment plant using the control plants that most closely resemble the treatment plants. We use nearest neighbor covariate matching to construct the sample of plants that we use in the DiD matching analysis. We pair treatment and control plants by selecting for each treatment plant *i* the *m* nearest neighbors that most closely resemble it in terms of selected covariates. The *m* nearest neighbors receive a weight *1/m* while the weights for all other untreated (non-exempt) plants are set equal to zero. In our base specification, we use 5 nearest neighbors.

As suggested by Abadie and Imbens (2006, 2011), we augment the matching estimation with a regression-based bias adjustment so as to mitigate potential bias introduced by poor match quality. That is, after matching the treated plants with *m* nearest neighbors, within-pair differences are adjusted using a parametric regression of the control outcome on a set of covariates.

Our specification matches exactly on the Statistics Finland TOL 2008 industry code. That is, control plants matched to each treated plant are required to be in the same industry as the treated plant. The industry classification is likely to be correlated with unobserved determinants of plant-level economic outcomes, including production technology characteristics and demand for the good produced by the plant.

Our continuous matching variables are plants' total energy use and share of electricity in total energy use in the pretreatment period. The larger the number of variables used for matching, the less accurately can one match on those variables that do not require exact matching. This speaks for a parsimonious specification.

Energy taxes paid would be a natural matching covariate. Unfortunately we only observe energy taxes for the exempt plants and thus cannot use them for matching. Instead, we employ energy use as a proxy for both a plant's energy tax burden and the plant's size.[8] Energy use is a better measure of plant size than the often-used measure employment in the case of energy intensive industries, where production processes are highly automized. Given a plant's total energy use, the share of electricity in total energy further approximates the plant's energy tax burden. The taxes on most fossil energy sources were increased substantially more than the tax on industrial electricity use in the 2011 energy tax reform, and have also been on the rise in the consequent years while the tax on industrial electricity use has remained at its 2011 level (see Figure 5.1. below). Thus, given total energy use, a higher share of electricity in a plant's energy mix is assumed to translate into a smaller energy tax burden.

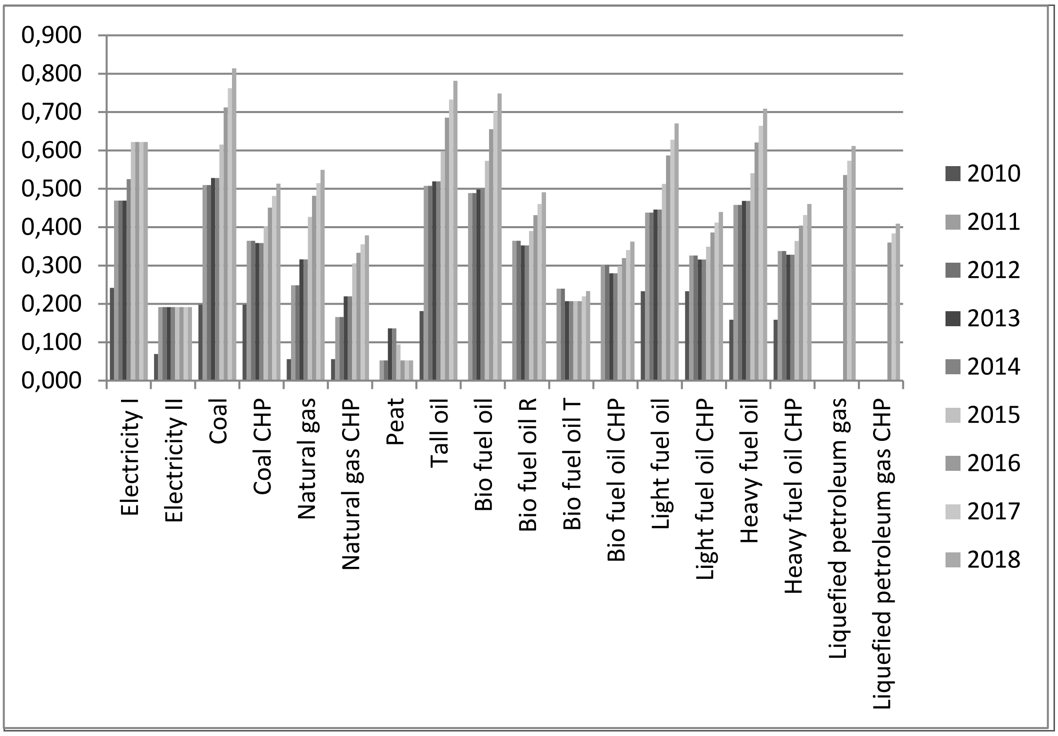
Figure 5.1 illustrates the differences in the tax rates for different energy sources and the changes in the tax rates following the 2011 energy tax reform. To enable straightforward comparison of energy taxes across energy sources we have expressed the taxes for all energy sources in terms of euro cents per MJ.

There are a variety of matching algorithms to choose from, and within the nearest neighbor matching algorithm used here several different choices of matching covariates can be justified. For example, plants' energy tax exposure could be measured by the ratio of electricity use to their total expenditure. We also experimented with a propensity score matching estimator, which seeks to describe the process by which the plants are selected into treatment. Although matching on propensity scores balances treatment and control plants across the set of covariates used to estimate the propensity scores, plants with very similar propensity scores may have different combinations of observable characteristics. In our case, we found that matching on propensity scores did not always imply a close match on observables. Consequently, our preferred matching

[8] Among the tax refund recipients, whose energy taxes we observe, energy use correlates highly with the energy taxes paid. We also experimented with calculating energy taxes on basis of plants' energy mix but did not obtain satisfactory results. The likely explanation for large discrepancies between calculated and realized energy tax payments is that fuels used in an industrial process are not subject to excise taxes. Process use and heating fuel use are not distinguished in our data.

specification and the results presented in this report rely on simple nearest neighbor matching.

Figure 5.1. Tax rates for different energy sources 2010-2018. The taxes comprise the energy content tax and CO_2-tax (security of supply and value added taxes are not included).



5.4 Descriptive statistics

Tables 5.1 and 5.2 present descriptive statistics of the financial and energy use variables of the plants used in the econometric analysis. Altogether 128 plants in our data first became eligible for the tax refund in 2011 or 2012 and continued to receive tax refunds every year thereafter. The table displays the plants that have been eligible for the energy tax refund starting 2011 or 2012 but not before, then the matched control plants, and the overall group of newly tax exempt and matched control plants.

Note that the tax exemption rule applies to firms, not to plants. A firm here refers to a tax identification number given by the Finnish Patent and Registration Office or the Tax Administration. While firms' taxes are determined at the level of each tax identification number, a tax paying unit is not necessarily equivalent to a corporate decision making entity.

Some corporations have collected all of their operations in Finland under one tax identification number, whereas others have divided their operations under several tax identification numbers so that even a single plant may be a tax paying unit. As the tax exemption rule applies to the total energy taxes paid by a tax identification number, plants within corporations that have collected all of their plants under one tax identification number are more likely to have energy tax payments that exceed the tax refund threshold than plants operated as separate tax paying units.[9] Plants within these two types of corporate structures may be similar in terms of size, gross output, value added and other characteristics, which helps us in finding matches for the treated plants that are similar in observable characteristics.

Overall plants in the new energy tax refund recipient group are still larger on average and more heterogeneous than plants in the full sample or non-recipient control plants, as measured by gross output, revenue, value added, or number of employees (Table 5.1). On average the new tax refund recipients also used more energy in total but were less energy efficient than the control plants. The energy mix of the newly exempt plants is less dominated by electricity (35 percent) than that of the control plants (44 percent). Of the new recipient plants, 91 percent belong in a multiplant firm. The proportion is lower in the group of the non-exempt control plants (41 percent).

Table 5.1. Descriptive statistics of the financial and energy use variables used in the econometric analysis.

	Energy tax exempt from 2011/2012			Control			Total		
Variable	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs
Gross output 2010, in million euros	98	125	128	22	29	116	62	100	244
Revenue 2010, in million euros	89	119	127	22	31	115	57	94	242
Value added 2010, in million euros	19	22	128	7	12	116	13	19	244
Wages per employee 2010, in 1000 euros	40	10	126	38	16	115	39	13	241
Employees 2010	184	193	128	85	117	116	137	169	244
Total energy use 2010, in TJ	767	1383	128	65	120	116	433	1063	244
Energy efficiency 2010, eur/GJ	669	1451	128	931	1462	116	794	1459	244
Share of electricity use 2010	0,35	0,22	128	0,44	0,23	116	0,39	0,23	244
Share of multiplant firms	0,91		128	0,41		116	0,67		244

Notes: We report the summary statistics of the plants for which information is available for the pre-treatment years and years 2015-2016. The matched control group is restricted to plants in the same TOL 2008 two-digit industry sectors as exempt plants. The matching algorithm matches each exempt plant to many control plants. Matching is carried out with replacement, in order to avoid issues arising from the order in which matches for each plant are selected. The overall number of matched controls is slightly smaller than the number of treated plants, which indicates that the same control plants are used as matches for several treated plants.

[9] The 50 000 euro deductible on energy tax refunds favors large tax paying units.

Table 5.2. Descriptive statistics on the energy use variables

	Energy tax exempt from 2011/2012			Control			Total		
Variable	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs
Electricity use 2010, TJ	264	685	125	21	44	116	147	508	241
Share of electricity use 2010	0,35	0,22	128	0,44	0,23	116	0,39	0,23	244
Heat use 2010, TJ	250	401	78	25	52	62	150	320	140
Share of heat use 2010	0,33	0,32	128	0,19	0,24	116	0,26	0,29	244
Coal use 2010, TJ	635	531	4	..	..	..	..	..	..
Share of coal use 2010	0,01	0,06	128	0,01	0,07	116	0,01	0,06	244
Gas use 2010, TJ	654	985	19	86	169	12	434	820	31
Share of gas use 2010	0,08	0,22	128	0,06	0,19	116	0,07	0,21	244
Peat use 2010, TJ	784	550	8	..	..	..	..	..	..
Share of peat use 2010	0,01	0,05	128	0,00	0,01	116	0,01	0,04	244
Light fuel oil use 2010, TJ	9	38	52	4	7	63	6	26	115
Share of light fuel oil use 2010	0,03	0,10	128	0,10	0,21	116	0,06	0,16	244
Heavy fuel oil use 2010, TJ	75	125	25	56	70	12	69	109	37
Share of heavy fuel oil use 2010	0,03	0,11	128	0,05	0,17	116	0,04	0,14	244
Wood fuels 2010, TJ	513	614	31	41	61	21	322	527	52
Share of wood use 2010	0,14	0,28	128	0,10	0,24	116	0,12	0,26	244

Notes: The number of observations for the quantity of each fuel type used indicates the number of plants that reported a positive quantity for the fuel in question. Notation “..” means that fewer than 3 observations were available for the cell, and descriptive statistics cannot be reported due to privacy constraints. We report the summary statistics of the plants for which information is available for the pre-treatment years and years 2015-2016. The matched control group is restricted to plants in the same TOL 2008 two-digit industry sectors as exempt plants. The matching algorithm matches each exempt plant to many control plants. Matching is carried out with replacement, in order to avoid issues arising from the order in which matches for each plant are selected. The overall number of matched controls is slightly smaller than the number of treated plants, which indicates that the same control plants are used as matches for several treated plants.

Figures 5.1 and 5.2 display distributions of the outcome variables for the last pre-treatment year 2010. In so far as the distributions overlap, we can be ensured that the exempt plants can be matched with non-exempt plants that had similar outcomes prior to the 2011 energy tax reform. The distributions demonstrate only partial overlap for gross output, revenue, value added, employees and total energy use. This means that plants in the upper tail of the exempt plants’ distribution for total energy use, for example, are compared to plants that are smaller in terms of total energy use. In terms of the variables used for matching, 80 percent of the exempt plants are within the support of the empirical distribution for year 2010 total energy use of the controls. All of the exempt plants are within the support of the empirical distribution of year 2010 electricity share of the controls. This means that for about 80 percent of the exempt plants it is be possible to find matches that are similar to them in terms of pre-treatment energy use. Thus, about 20 percent of exempt plants are compared to plants that are smaller in terms of their pre-treatment energy use.

While the newly tax exempt plans are larger than the control plants in terms of scale, the two groups are more similar in terms of variables measuring intensity (Figure 5.2). For wages per employee, the share of electricity in total energy use, and energy efficiency the distributions for exempt plants are overlapped by the distributions of the matched control plants. Recall also that we enforce strict matching within each TOL 2008 two digit industry – that is, the matches for each treated plant are selected from the same industry as the treated plant.

The bottom right panel of Figure 5.2 displays the ratio of electricity to total expenditure for the exempt and matched non-exempt plants. The ratio of electricity to total expenditure is an alternative proxy for the energy tax burden of plants. As Figure 5.2 shows, the exempt and matched non-exempt plants exhibit similar, overlapping distributions for the ratio of electricity to total expenditure.[10] Thus, if the objective of the energy tax refund was to lessen the energy tax burden of the most energy intensive firms, it did not really succeed in sorting out only particularly energy intensive operators. The energy tax refund is determined based more on the scale of energy use than the intensity of energy use, with the consequence that plants with similar energy intensities can receive different tax treatment.

Overall the summary statistics and distributions for the pre-treatment values of the outcome variables highlight a limitation of our matching strategy. Ideally, we would like to match each newly exempt plant with a large number of control plants in the same industry with similar historic outcomes. However, the number of control plants with very similar historic scale outcomes is limited. In order to avoid potential bias created by pre-treatment differences, our matching procedure is combined with a difference-in-differences approach. That is, we do not compare outcomes (for example, revenue) between newly tax exempt matched non-exempt plants, but the change in the outcome (for example, revenue) between 2010 (before the tax reform) and post-reform years. Thus, the identification strategy is based on the assumption that conditional on the matching covariates, the outcomes of the exempt plants and non-exempt control plants would have followed parallel trends had the tax exemption not been extended to include the newly exempt plants in 2011-2012. The following section will start with a comparison of the pre-treatment trends in the outcome variables.

[10] Due to many missing values for total expenditure, a variable not used in our analysis otherwise, in the last pre-treatment year 2010, the ratio of electricity use to total expenditure was computed as the average for all the pre-treatment years 2007-2010 in our data.

Figure 5.1. Comparison of pre-treatment distributions of outcome variables for newly exempt (from 2011/2012 onwards) plants and matched non-exempt plants

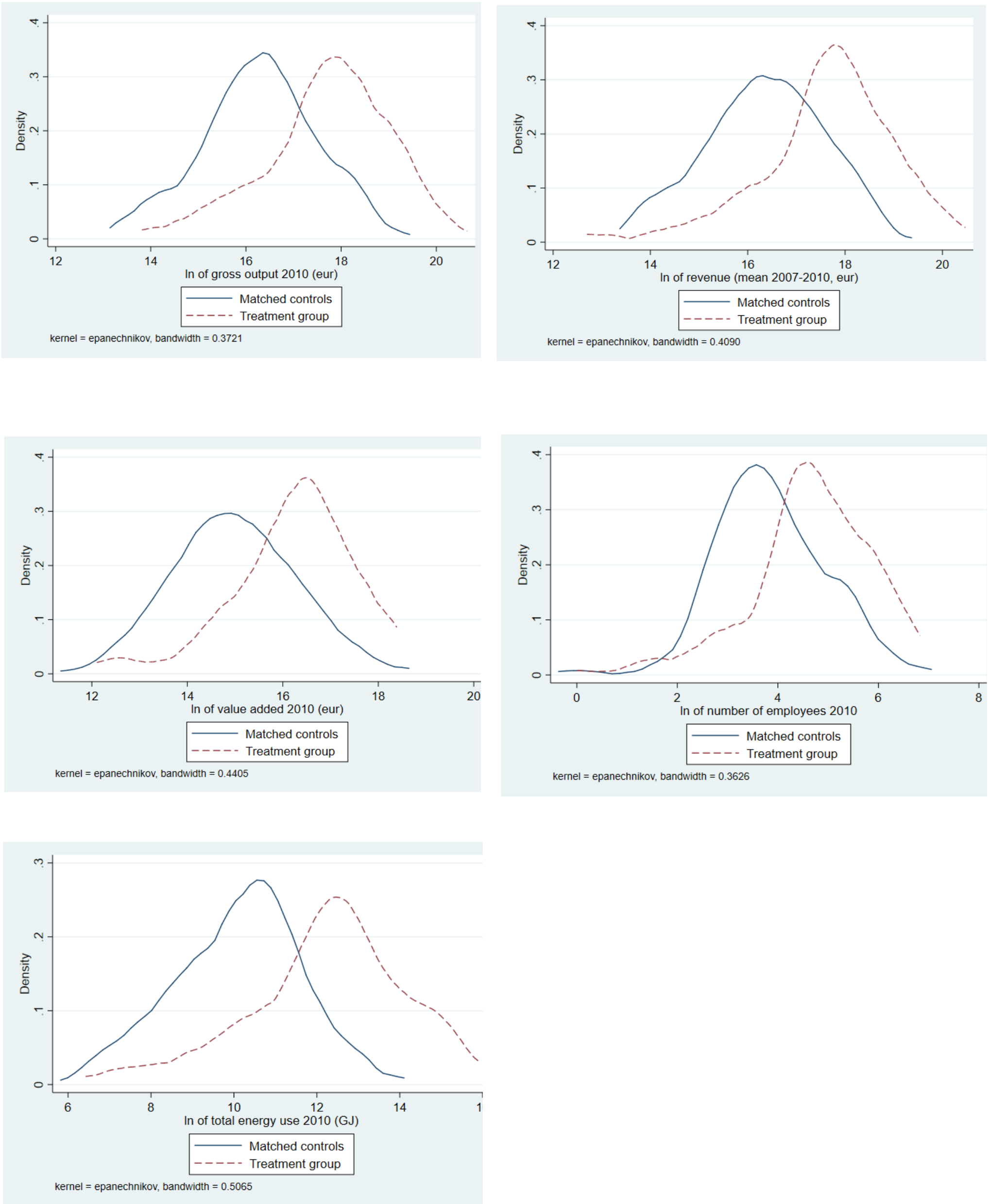
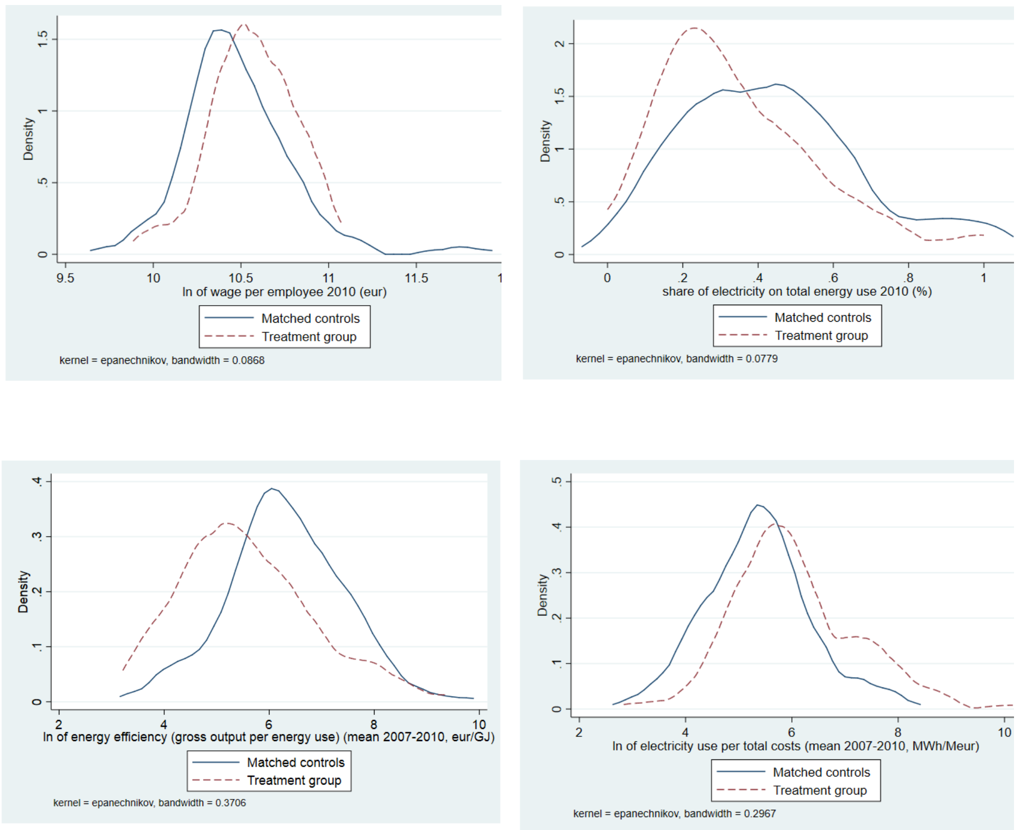


Figure 5.2. Comparison of pre-treatment distributions of outcome variables for newly exempt (from 2011/2012 onwards) plants and matched non-exempt plants



6 Results

We start out by plotting graphs of the economic and energy outcomes of the newly exempt plants and the matched control plants both before the 2011 energy tax reform and the change in the tax exemption threshold. The graphs in Figures 6.1 to 6.3 serve both to illustrate the post-reform differences, if any, in the outcomes of the newly exempt and non-exempt plants, and to evaluate the underlying assumption of parallel trends. While it is not possible to test the assumption of parallel trends in the outcomes of the tax exempt and matched control plants had the tax exemption rule not been changed, the assumption is more plausible if the two groups exhibited parallel trends prior to the 2011 tax reform.

Based on visual observation, the trends for the outcome variables mostly follow parallel trends prior to 2011. Only for value added, we observe slightly different movement between 2007 and 2008. Statistical tests confirm this visual observation.[11] The trends also remain roughly parallel for the exempt and non-exempt plants after 2011 although there is notable year to year variation. No unidirectional difference is apparent in the movements of gross output, revenue, value added or wages for the two groups of plants. For employees, total energy use and gross output relative to energy use (a measure of energy efficiency) there is a gap between the exempt and non-exempt firms that seems to widen some for gross output relative to energy use, and close some for employment towards the end of the period that our data cover.

Table 6.1 shows how significant the differences in the outcomes of the exempt and non-exempt plants are from a statistical point of view. Our outcomes of interest are the changes in plant-level economic performance and energy use measures. For a long-term view of the overall effects of the tax exemption on the plants that became exempt in 2011-2012, we analyze changes in plant-level outcomes between the last pre-treatment year 2010 and years 2015-2016. We report results generated using log transformed data, so the average treatment effect on the treated[12] can be interpreted as the estimated average effect in percentage terms. Standard error estimates have been constructed using the Abadie and Imbens (2006) variance formula. Exempt plants were matched to the five nearest neighbors within the same TOL 2008 two-digit industry.

Recall that the estimates in Table 6.1. compare the most recent years in the data, 2016-2015, to the last pre-reform year 2010. The estimated coefficient for gross output is -

[11] We reject the null hypothesis on no trend difference at the 95 percent level for value added in 2009 and for employees in 2008, that is, in two out of 21 hypothesis tests.
[12] That is, the average effect of the energy tax exemption on plants that have been exempt from 2011-2012 onwards and were not exempt prior to 2011.

0,37, which suggests that gross output grew on average 37 percentage points less between 2010 and 2015-2016 among exempt plants than among non-exempt plants. The coefficient is significant at the 1 percent level. However, the trends for gross output indicate substantial year to year variation in the average gross output development. The long-term view presented here should in further research be complemented by an overall view for the post-reform years. Nonetheless, the descriptive evidence in Figure 6.1 does not suggest that the overall view would differ from the long-term view in terms of the direction of the impact.

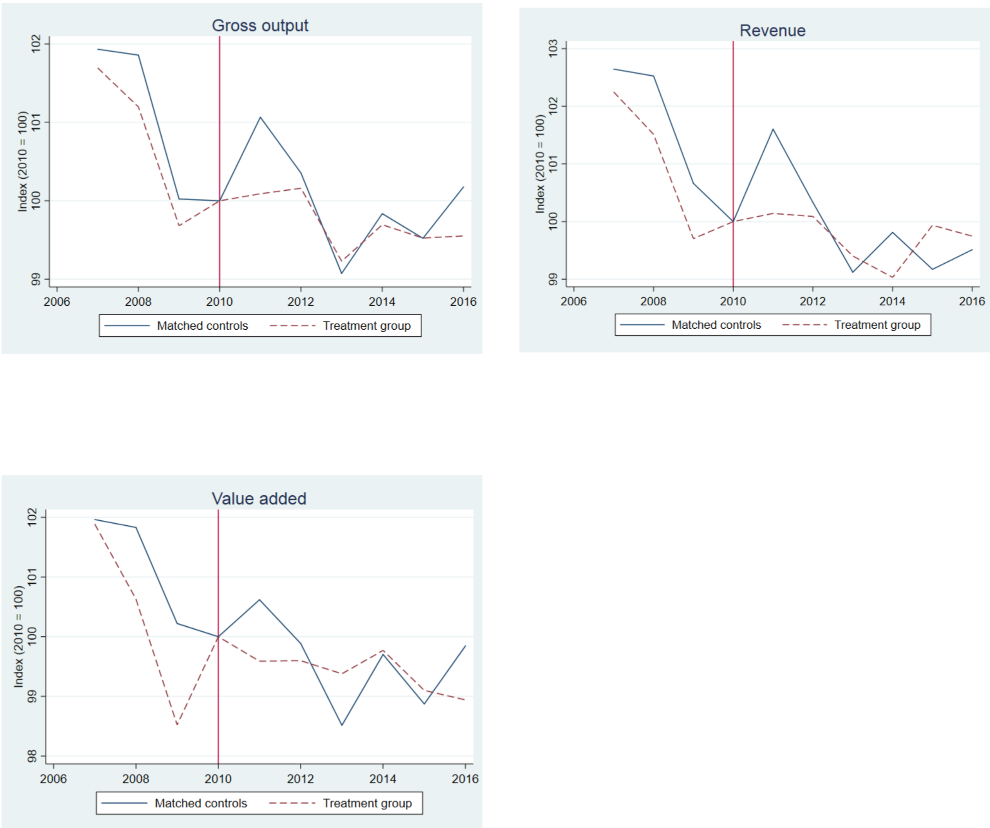
The gross output variable measures the value of a plant's output. Thus, the negative effect on gross output is consistent both with firms producing less, and with firms charging lower prices. We cannot distinguish between these two responses as we do not observe plants' physical output.

The estimated coefficients for revenue, value added, wages per employee, employees and total energy use are not statistically significant at conventional levels. The point estimate for revenue is negative, for value added positive but much smaller in magnitude. The point estimate for wages is negative, the point estimate for employees positive. Both are close to zero in magnitude. The 95 percent intervals for these coefficients are quite wide and encompass both negative and positive values. Thus, for these outcome variables both negative and positive effects are reasonably compatible with the data. Overall, the results are most compatible with the energy tax exemption having no effect on the long-run growth in revenue, value added, wages, employees or total energy use, among the plants that have been tax exempt from the 2011 reform onwards.

The estimated coefficient for energy efficiency (gross output per total energy use) is -0,52 . The coefficient is significant at the 1 percent level. Thus, plants that became tax exempt in 2011-2012 appear to have become less energy efficient between 2010 and 2015-2016 whereas the energy efficiency of non-exempt plants has overall remained close to its 2010 level (Figure 6.3). The results suggest a widening gap between the energy efficiency of the newly exempt and non-exempt plants, to the benefit of the non-exempt plants. However, as our measure of gross output is not a physical but a monetary one, the result does not necessarily indicate that newly exempt firms are using more energy per unit of physical output – it could be the case that the negative effect on energy efficiency stems from charging lower prices rather than different developments in the amount of output produced per unit of energy.

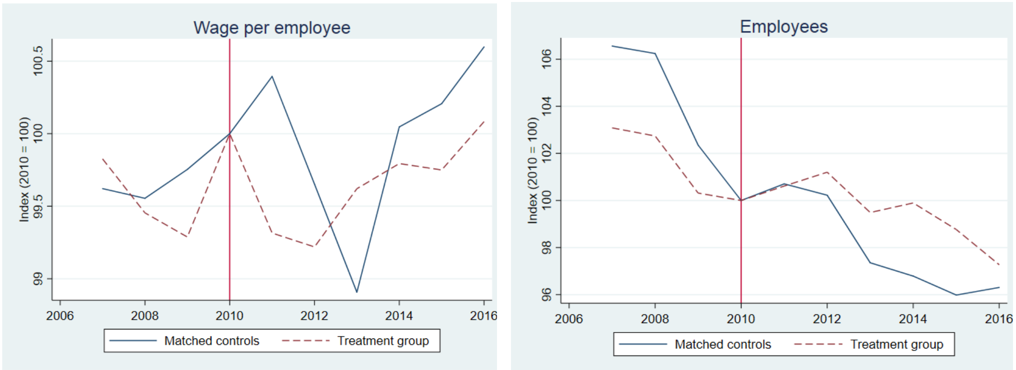
The trends in the outcome variables shown in Figures 6.1 to 6.3 exhibit notable year to year variation. This should be born in mind when interpreting the results. For most outcome variables, no clear pattern emerges for the differences between the plants that first became tax exempt after the 2011-2012 energy tax changes, and non-exempt plants. Based on visual observation, the difference is unidirectional to a degree for gross output and energy efficiency. Overall the initial results presented here are most compatible with no important effect of the energy tax exemption on revenue, value added, wages, employees or total energy use and a negative impact on gross output and energy efficiency. The results refer to the average effect of the tax refunds on plants that first became tax exempt in 2011-2012, after the energy tax refund system was extended by lowering the exemption threshold.

Figure 6.1. Gross output, revenue and value added for newly exempt (from 2011/2012 onwards) plants and matched non-exempt plants, 2007-2016



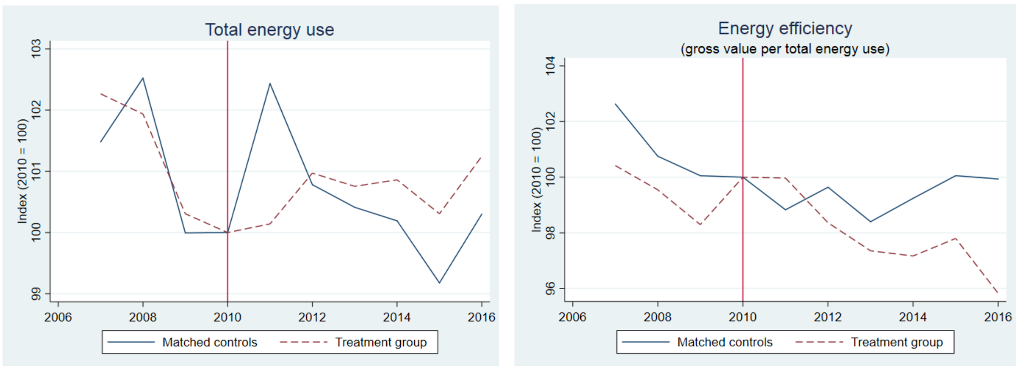
Note: Graphical representation of the difference-in-differences approach. The effect of the energy tax exemption is assessed statistically by comparing the trends of the exempt plants and the matched non-exempt plants. Notation: treatment group includes plants that became tax exempt in 2011/2012, control group matched non-exempt plants.

Figure 6.2. Wages and employees for newly exempt (from 2011/2012 onwards) plants and matched non-exempt plants, 2007-2016



Note: Graphical representation of the difference-in-differences approach. The effect of the energy tax exemption is assessed statistically by comparing the trends of the exempt plants and the matched non-exempt plants. Notation: treatment group includes plants that became tax exempt in 2011/2012, control group matched non-exempt plants.

Figure 6.3. Total energy use and energy efficiency (gross output per energy use) for newly exempt (from 2011/2012 onwards) plants and matched non-exempt plants, 2007-2016



Note: Graphical representation of the difference-in-differences approach. The effect of the energy tax exemption is assessed statistically by comparing the trends of the exempt plants and the matched non-exempt plants. Notation: treatment group includes plants that became tax exempt in 2011/2012, control group matched non-exempt plants.

Table 6.1. The average effect of the energy tax exemption on 2015-2016 outcomes

Dependent variable	Gross output (Log)	Revenue (Log)	Value added (Log)	Wages per employee (Log)	Employees (Log)	Total energy use (Log)	Energy efficiency (Log)
Coefficient	-0,39***	-0,18	0,03	-0,03	0,01	-0,08	-0,52***
SE	0,10	0,16	0,16	0,05	0,07	0,08	0,11
p	0,00	0,26	0,87	0,53	0,89	0,31	0,00
Lower bound of 95 percent confidence interval	-0,57	-0,48	-0,29	-0,12	-0,13	-0,24	-0,73
Upper bound of 95 percent confidence interval	-0,20	0,13	0,33	0,06	0,16	0,08	-0,31
Number of observations	244	243	236	244	246	246	245
Number of treated	128	127	119	127	129	129	128
Number of controls	116	116	117	117	117	117	117

The initial results are in line with both the results for Finland's energy tax refunds in Harju et al. (2016) and on other empirical papers on the impact of energy prices differences on manufacturing firm performance. We complement the work in Harju et al. (2016) by adding a more long-term view – where Harju et al. (2016) only had data for the three post-reform years 2012-2014, we are able to look at a time period five years after the reform, where plants will have had more time to adjust to the changes in the tax schedule. We analyze more detailed plant-level data, where Harju et al. (2016) considered firm-level (tax identification number) information. We use an identification strategy that allows for estimating the causal impact of the tax exemption policy, where Harju et al. (2016) analyzed the association of the tax exemptions with firm performance. We also added data on plants' energy use, not included in the analysis by Harju et al. (2016). Overall, our results are in line with those by Harju et al. (2016). Harju et al. found no evidence of a robust, statistically significant association between energy tax refunds and firm performance. Our findings are most compatible with no effect on other measures of manufacturing plant performance, but a negative impact on the growth of gross output, due either to less output or charging lower prices. Figure 6.1. suggests that this discrepancy between our results and those in Harju et al. (2016) could perhaps be explained by the difference in the time periods that the two analyses focus on. Future analysis applying our identification strategy to the period 2012-2016 would shed light on how likely this conjecture is likely to be correct.

The initial findings are also in line with other research that has studied the effects of similar tax exemptions on manufacturing firm performance in other EU countries. Gerster and Lamp (2018) analyzed a tax exemption to large manufacturing plants in Germany. Newly exempt plants were found to increase their energy use some but their sales did not increase. The number of employees in newly exempt plants decreased some, which

Gerster and Lamp suggest could be because they substituted bought electricity for generation on site. Flues and Lutz (2015) studied the effects of German electricity taxation exploiting a threshold in the electricity tax system, which assigned a lower tax rate to industries with high electricity use. They found no effect of the tax relief on firm revenue, exports, value added, investments or employment. Martin et al. (2014) analyzed the effects of energy taxes in the United Kingdom, where energy-intensive manufacturing firms were granted an 80 percent concession in their energy taxes if they committed to voluntary agreements to reduce their energy use or carbon emissions. Martin et al. found that paying the full tax had no effect on production, productivity or employment but that it reduced firm energy intensity notably relative to firms that obtained the tax relief.

When interpreting the results, the cost saving provided by the energy tax exemption may provide some perspective. The average cost saving in terms of total expenditure is on the order of 1 percent. In terms of electricity costs, the saving provided by the tax exemption averages 6 percent. Marin and Vona (2017) utilized a detailed data set on manufacturing plant energy expenditure and energy use and found energy prices to have a small negative impact on employment and productivity: a 10 percent increase in energy prices decreased employment by 2,6 percent and productivity by 1,1 percent. Given the size of the average electricity price difference generated by Finland’s energy tax exemption, an overall employment increase of 1,6 percent would have been in line with Marin and Vona’s results. Possible explanations for the divergence between Marin and Vona’s results and ours, of no statistically significant effect on employment, could be the size of the electricity cost differential or different industrial structures; Finland’s tax exemption applies primarily to process industries whereas Marin and Vona examined a wide range of industries including both process industries and discrete manufacturing.

7 Conclusion

The results presented in the previous section are overall most compatible with no important effect of the energy tax exemption on revenue, value added, wages, employees or total energy use, and a negative impact on gross output and energy efficiency. The results refer to the average effect of the tax refunds on plants that first became tax exempt in 2011-2012. There are several possible explanations for the negative effect on gross output. First, as outlined in Section 3.2, the mechanism through which one would expect the energy tax refund to affect manufacturing firms export performance is cost competitiveness. The negative effect on gross output is consistent both with firms producing less, and with firms charging lower prices. We cannot distinguish between these two responses as we do not observe the quantity of plants' physical output but only the value of output in monetary terms. Charging lower prices would be consistent with the assertion that lower unit costs enable producers to reduce their prices and increase their sales. One would then anticipate that the effect on revenue would go in the same direction as the effect on gross output. The estimated effect on revenue is not statistically significant, but the point estimate is negative.

Overall the results are most compatible with no important effect on the number of employees, wages or energy use, which would be consistent with the effect on gross output arising from charging lower prices rather than reducing the quantity of output. On the other hand, the industries eligible for the energy tax refunds are capital intensive process industries, and relatively small output changes may not be manifested as notable changes in employment or energy use. For example in the lumber and paper industries, raw materials are a significant cost item (44 percent and 38 percent in 2013, respectively, according to Viitanen and Mutanen 2015). Whether output changes are reflected more notably in raw material inputs than in labor and energy inputs would be an interesting further research question.

Electricity use relative to total expenses follows a similar distribution among exempt and matched non-exempt plants. If using this measure for energy intensity, the tax refund system does not really succeed in sorting out only particularly energy intensive operators as refund recipients. The energy tax refund is determined based more on the scale of energy use than the intensity of energy use, with the consequence that plants with similar energy intensities can receive different tax treatment.

The results presented here are the first results of a larger research agenda. They will be complemented with an overall view for the years 2012-2016 as well as alternative matching specifications to study the robustness of the results to different matching covariates. Comparison of investment behavior among exempt and matched non-exempt plants would be an interesting extension in that could help distinguish whether lower prices or less output per unit of energy is the more likely explanation for the negative effect on energy efficiency. Future work on possible effects on the use of raw material inputs would also be informative in terms of explaining the missing employment and energy use impacts.

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