Energy Economics 133 (2024) 107552

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

The impact of solar PV subsidies on investment over time - the case of Sweden

Hanna Rydehell [a,*], Björn Lantz [a], Ingrid Mignon [a], Johan Lindahl [a,b]

[a] Department of Technology Management and Economics, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden
[b] Becquerel Sweden AB, Staffansvägen 14, SE-741 42 Knivsta, Sweden

ARTICLE INFO

Keywords:
Photovoltaics
Economic policy
Subsidy
Investor groups
Sweden

ABSTRACT

Over the past decade, different economic incentives have been created to increase investments in solar photovoltaics (PV). Although research outlines that investors in renewable electricity technologies (RET) are heterogeneous, policies have not taken this into account when designing subsidy programs. This paper aims to analyse the relationship between policy incentives and the willingness to invest in PV systems for different investor groups, including households, companies, associations, and public organizations. Using data from all applications to the capital subsidy program for PV in Sweden between 2009 and 2021, we analyse the impact of the subsidy level on investments over time. Our analysis shows that the subsidy has had a positively significant impact for households and private companies as investor groups. However, we also found that other variables have had a significantly positive or negative effect on the willingness to invest for different investor groups. This stresses the need of going from "one size fits all" policies to policies that better adapted to different investor characteristics. To meet the urgent need to accelerate the diffusion of RETs, our results show the impact of investor heterogeneity on policy responsiveness and provide avenues for the design of targeted policies.

1. Introduction

A transition from fossil-based to renewable electricity technologies (RETs) is crucial to limit the negative impacts of climate change on humanity and on the planet. The solar photovoltaic (PV) technology is one of the RETs that has received a lot of attention over the last decade, both among investors and in the scientific literature. With technology prices going down and electricity prices going up, investing in solar PV has become an option for an increasing share of organizations and households (e.g., Aydın et al., 2023; Spiller et al., 2023). Between 2010 and 2021, the installed solar PV capacity has grown from 39.2 GW to 891.9 GW, making it the second-largest absolute generation growth among all RETs in 2021, after wind (IEA, 2022b). Nevertheless, an average annual generation growth of 35% is still needed in the period 2022–2030 in order to reach the net-zero emissions targets by 2050, as set forth by the Paris Agreement (United Nations, 2015).

To reach such ambitious targets, an increase in private and public investments is crucial. This is the reason why many countries have established economic policies aimed at promoting investments in RETs, including the PV technology (e.g., Lüthi and Wüstenhagen, 2012; Polzin et al., 2015; Tolliver et al., 2020). Among these policies, green tradable certificates, feed-in tariffs, capital subsidies, tax credits and net-metering have been used to a large extent, especially in Europe (Dusonchet and Telaretti, 2015; Polzin et al., 2019). These economic incentives aim at lowering the risks and cost of the investment and thereby aiming to influencing individuals and organizations' behaviour towards investing in RETs. For instance, capital subsidies facilitate the investment decision by lowering the upfront investment cost (Polzin et al., 2019).

Traditionally, incentive policies have been based on a number of assumptions regarding individuals and organizations that invest in renewable electricity production (Bergek et al., 2013). One assumption is that investors in RETs are economically rational and that their main motivation for investing is an economic one (Wüstenhagen and Menichetti, 2012). Another assumption is that RET investors are either professional investors, i.e., utilities or project developers (e.g., Best, 2017; Bürer and Wüstenhagen, 2009; Yang et al., 2022), or households (see the review by Kastner and Stern, 2015). However, more recent empirical studies have stressed the limitations of these assumptions. For instance, studies have shown that actors' investment decisions are in fact affected by their limited foresight of the future, as well as their different

---

* Corresponding author.
E-mail addresses: hanna.rydehell@chalmers.se (H. Rydehell), bjorn.lantz@chalmers.se (B. Lantz), ingrid.mignon@chalmers.se (I. Mignon), lindahjo@chalmers.se (J. Lindahl).

https://doi.org/10.1016/j.eneco.2024.107552
Received 16 October 2023; Received in revised form 22 March 2024; Accepted 12 April 2024

perceptions and expectations of, for example, technology costs, electricity prices and grid tariffs (e.g., Barazza and Strachan, 2020; Gautier and Jacqmin, 2020; Sheha et al., 2021; Wüstenhagen and Menichetti, 2012). Likewise, studies have demonstrated that, rather than being limited to professional investors and households, RET investors in fact include a variety of organizations, including diversifying companies, companies specialized in renewable electricity production, associations, public organizations, farmers, individuals and households (Bergek et al., 2013; Karneyeva and Wüstenhagen, 2017).

Qualitative studies have found that this heterogeneous group of RET investors has different driving forces for investing (Bergek and Mignon, 2017; Hansen et al., 2022; Palm, 2018) and different perceived barriers (Heiskanen and Matschoss, 2017; Mignon and Bergek, 2016a). Hence, they do not respond to existing policies and to institutional signals the same way (Kastner and Stern, 2015; Mignon and Bergek, 2016b). Yet, this heterogeneity within the RET investor group is seldom acknowledged when measuring the impact of policies. As a consequence, the extent of the policy impact on different RET investor categories, e.g., companies, households, public organizations, associations, remains unclear. The aim of this paper is therefore to analyse the relationship between policy incentives and the willingness to invest for different types of investors.

In this article, we focus on the case of Sweden, which is one of the countries that has had such policy incentives between 2009 and 2021. This study considers the whole group of 70,000 investors (adopters) that has applied for the subsidy during the program period, considering different types of adopters included in the group, i.e., households, companies, public organizations and associations.

The paper is structured as follows. In Section 2, we introduce the policy context of Sweden with a specific focus on the subsidy program. In Section 3, the hypotheses are presented and motivated. Section 4 presents the data and the method. Results are then presented in Section 5 and discussed in Section 6. We end the paper with suggestions for future research in Section 7.

2. The Swedish solar PV subsidy program

The Swedish solar PV market has been developing over decades and is today considered to have reached the stage of early majority, according to Rogers.' (2003) diffusion life cycle (Andersson et al., 2021; Sommerfeldt et al., 2022). In Sweden, such market growth has been supported through a variety of investment subsidies, particularly targeted at new investments in solar PV (IEA, 2022a). From April 2005 to the end of 2008, support for energy efficiency in public premises existed, where solar PVs were included as one of the eligible measures for which it was possible to apply for direct capital support. Later, in mid-2009, a new subsidy program was introduced opening up opportunities for other actors to apply for direct capital support (Government Offices of Sweden, 2009). The goal of the subsidy program was to contribute to the transformation of the energy system and to industrial development in the field of energy technology, aiming at increasing the use of solar PV systems and the number of actors handling such systems, as well as decreasing the costs of such systems. The subsidy program stayed in place until 2021, although it was modified on several occasions, e.g., the support level was decreased to cope with falling technology prices and a higher market demand (IEA, 2022a) (see Table 1 and Fig. 1).

The investors' interest in the subsidy program was high from its introduction and for several years, the number of subsidy applications was higher than the budget allocated (IEA, 2022a; Swedish Energy Agency, 2018). Private households constitute the largest share of applications, whereas companies (including housing associations, economic associations, limited and incorporated companies) were the group applying for the largest share of economic support (Swedish Energy Agency, 2018).

Fig. 1 shows the budget allocated for the subsidy program over the years.

Table 1
Overview of changes in the direct capital subsidy ordinance, support level and duration (based on IEA, 2022a).

Ordinance	Start date	Maximum coverage of the installation costs	Initial stop date
2005:205 Energy efficiency improvements in public premises	2005-04-14	70%	2008-12-31
2009:689 Support for solar PV	2009-07-01	55% for large companies 60% all others	2011-12-31
2011:1027 change of 2009:689	2011-11-01	45%	2012-12-31
2012:971 change of 2009:689	2013-02-01	35%	2016-12-31
2014:1582 change of 2009:689	2015-01-01	30% companies 20% all others	2016-12-31
2016:900 change of 2009:689	2016-10-13	30% companies 20% all others	2019-12-31
2017:1300 change of 2009:689	2018-01-01	30%	2020-12-31
2019:192 change of 2009:689	2019-05-08	20%	2020-12-31
2020:489 change of 2009:689	2020-06-30	20%	2021-06-30
2020:1263 change of 2009:689	2021-01-15	10% companies	2021-09-30

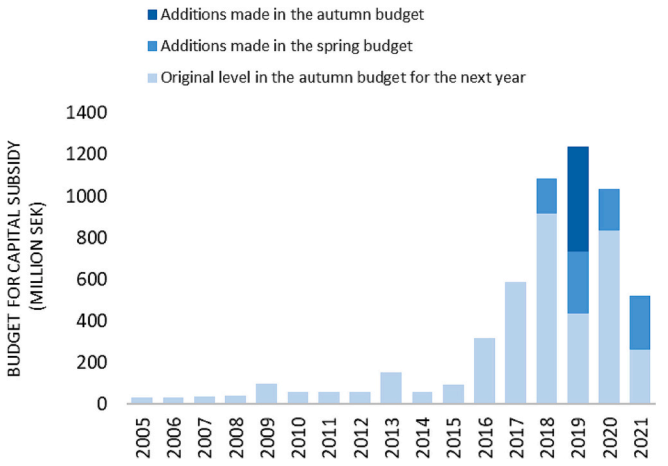

Fig. 1. The annual budget of the direct capital subsidy program (IEA, 2022a).

It should be noted that the level of support differed between investor groups, especially between companies and other actors, for example, private household and public organizations (see Table 1). In a report from the Swedish Energy Agency in 2014 (Swedish Energy Agency, 2014), it was proposed that the support level would decrease from 30% to 10% for companies (with the exception of agricultural properties were the suggested level was proposed to be decreased to 25%), and the support would be completely phased out for households and housing associations by the end of 2015 or beginning of 2016. In June 2020, it was announced by the government that the subsidy was been interrupted and that only installation completed by June 30, 2021 would be subsidized. At the same time, it was announced that the last day to apply for the subsidy would be July 7, 2020. In September 2020, the government extended the subsidy for public buildings and companies, proposing a 10% support level for 2021. For private households (individuals), the subsidy was replaced by a green tax deduction in 2021 (Government Offices of Sweden, 2020).

3. Literature review and hypotheses development

In classic economic theory, the *law of demand* says that, ceteris paribus, as the price of a good decreases, the quantity demanded will increase, conversely, as the price of a good increases, the quantity demanded will decrease (Hildenbrand, 1983). According to this, a reduction of the cost to invest in a technology will impact the quantity demanded in the market. For new technologies, such as solar PV, the investment cost is initially high in the market. To increase the demand for such technologies and support the transition of the energy system, economic policy instruments play an important role (e.g., Polzin et al., 2019).

Different policy instruments have been developed over the years to stimulate investments in RETs, with feed-in-tariffs and tradable green certificates being the two most commonly deployed policy incentives (Bergek and Jacobsson, 2010; Ciarreta et al., 2017; Dinica, 2006; Finon and Perez, 2007; Yu et al., 2022). Simplified, feed-in-tariffs are a price-based policy, while tradable green certificates are a quantity-based policy. While both policies were initially expected to lead to similar outcome in terms of RET deployment, research has demonstrated that feed-in-tariffs lead to greater amount of renewable energy in electricity production than green certificates do (Menanteau et al., 2003; Mitchell et al., 2006; Ringel, 2006), when accounting for investment risk (Wüstenhagen and Menichetti, 2012). In contrast, regarding economic efficiency, tradable green certificates have been said to lead to a lower social cost for nations (Bergek and Jacobsson, 2010; Ringel, 2006). Even though both policy schemes have their pros and cons, they have both led to increased growth of RETs (Resch et al., 2007), driving the technological development (e.g., Jenner et al., 2013; Johnstone et al., 2010; Karneyeva and Wüstenhagen, 2017; Menanteau et al., 2003).

Nevertheless, when it comes to decentralized systems such as solar PV systems, more nuanced policy impact has been reported. In Sweden, the experience of a tradable green certificate system showed that, while the policy had contributed to accelerating the deployment of centralized systems, such as wind power plants, it was not adapted to encourage the deployment of solar PV (Haegermark et al., 2017; Palm, 2015). One reason for that is that while PV systems are recognized for their minimal maintenance and fuel costs, they necessitate substantial upfront investments, which is a barrier, especially for investors that have a limited access to start capital or in contexts of high uncertainty related to the evolution of the technology price (Mundaca and Samahita, 2020). Consequently, some countries have implemented policies aimed at reducing the initial investment as an incentive for PV adoption to increase the willingness to invest in solar PV system. Direct subsidies are currently comprising for approximately 16% of the global market share, are a prevalent form of support for PV systems (IEA, 2022c). Research on investment subsidies for RETs have found support for an increased likelihood to switch energy system as it reduces costs and risk to invest as well as providing motivation and interest to develop and use RETs, such as solar PVs (Sadorsky, 2021; Solangi et al., 2011; Zhang et al., 2016). Nevertheless, for a clear positive impact on the willingness to adopt solar PV, it has been stressed that investors need to be able to rely on the stability of the investment subsidies over time (Mundaca and Samahita, 2020).

Traditionally, in the energy policy literature and in the policy debates, a number of assumptions have been made related to RET investors. One such assumption has been that RET investors constitute a homogenous group, mainly composed of large utilities aiming for profit-maximization guided by economic rationality in their decision-making (e.g., Fleten et al., 2007; Gross et al., 2010). In recent years, an alternative perspective has emerged, emphasizing that RET investors are, in fact, a heterogeneous group influenced by different motives and recourses, who adopt different investment behaviours (e.g., Bergek et al., 2013; Hansen et al., 2022; Masini and Menichetti, 2012; Wüstenhagen and Menichetti, 2012). Rather than considering RET investors as a homogenous group, these authors emphasize investor diversity, for instance with regards to revenue models (e.g., Karneyeva and Wüstenhagen, 2017), sizes or organizational forms (Agterbosch et al., 2004; Bergek et al., 2013; Loock, 2012). In this research, authors have shown that different types of RET investors react differently to different policies. For example, households are more willing to invest in RETs when such investments are subsidized by tax policies (e.g., tax deduction) (Sardianou, 2007; Sardianou and Genoudi, 2013). Residential investors are also motivated to invest by the possibility to self-consume the electricity produced (Karneyeva and Wüstenhagen, 2017), yet tend to underestimate the value of the future benefits of electricity production and focus instead on the immediate investment cost (De Groote and Verboven, 2019). As a result, they are more likely to adopt solar PV technology when incentivized by an investment subsidy scheme. This may also be because households' overall capacity to invest (and thus their decision to do so) depend on their income (Lekavičius et al., 2020). Thus, investment subsidies provide a possibility to mitigate the impact of high investment cost (Selvakkumaran and Ahlgren, 2019).

Although research has demonstrated that households' decision to invest in solar PV depend on a variety of different motives (e.g., Palm and Tengvard, 2011) economic motivation are more prominent over time (Palm, 2018), and for RETs subsidies may even be more important for investment decisions than for example environmental concerns (García-Maroto et al., 2015). Mundaca and Samahita (2020) studied the economic and non-monetary factors for households' decision to investing in solar PVs and found that subsidies and peer effects increases the likelihood to invest. Although decisions to invest in solar PV by households have been shown to be affected by peers (e.g., Palm, 2017), incentives that reduce the investment cost are evident in previous research. For example, Jacksohn et al. (2019) found that for households, investment decisions in solar PV systems were mainly driven by publicly provided monetary incentives. Same was found by Fleiß et al. (2017), who studied citizen engagement (i.e., households) in investing in solar PV. These results suggest that economic incentives are major constructs in shaping a positive willingness to invest in solar PVs (e.g., Briguglio and Formosa, 2017; Mundaca and Samahita, 2020; Skordoulis et al., 2020). Thus, we propose the following hypothesis:

H1. The subsidy level has a positive relationship with the willingness to invest in solar PV for households.

Regarding non-residential investors, subsidy schemes have been demonstrated to reduce perceived risk of investment (Niesten et al., 2018). As for companies that intend to invest in RETs, particularly in the domain of solar PV, the provision of subsidies for initial investments holds the potential to incentivize augmented installed capacity and contribute to the mitigation of the future Levelized Cost of Electricity (LCOE) associated with solar power (Li and Huang, 2020). Yet, Karneyeva and Wüstenhagen (2017) found that for utilities with revenue-based business models (e.g., limited and incorporated companies) feed-in-tariffs can be attractive in the decision to invest in RETs. Thus, direct subsidies may have less effect on the actual decision than other incentives from the government. However, Brudermann et al. (2013) focusing on the PV investment criteria of farmers, showed that economic motives, such as short payback period, lower costs for electricity or secure investment, are most influential.

For a diversity of companies, behaviour theory would argue for economic rationality in the investment decisions, and thus, reducing the risk to invest in RETs would ultimately be a support mechanism for willingness to invest (e.g., Menanteau et al., 2003; Mitchell et al., 2006; Niesten et al., 2018). More specifically, investment subsidies may yield more investments overtime and are perceived as effective in reducing technological costs (e.g., Frey and Mojtahedi, 2018; Özdemir et al., 2020). Increased direct capital subsidy has even been demonstrated to, in certain context, intensify the risk of overcapacity of in companies focusing on solar PV (Zhang et al., 2016). Based on this, we propose the following hypothesis:

H2. The subsidy level has a positive relationship with the willingness to invest in solar PV for companies.

Except companies, other non-residential investors constitute the diversity of organizations investing in RETs, including associations and public organizations (e.g., Bergek et al., 2013; Karneyeva and Wüstenhagen, 2017). In similarity to companies, investors in the non-residential sector may perceive the risk of investing in RETs to be lower if subsidy schemes are available (Niesten et al., 2018). Frey and Mojtahedi (2018) found that subsidies for solar PV investment intensified the willingness to invest by actors in the non-residential sector. Also, Reindl and Palm (2021) identified subsidies as an enabler for investment decisions by non-residential investors. Yet, the heterogeneity in ownership structure between different investors in the non-residential sector may create different intentions for decision to invest in solar PV (Reindl and Palm, 2021) due to different legal regulations and conditions (Kesidou and Sorrell, 2018; Warneryd and Karltorp, 2020).

Associations, encompassing multi-owned structures, represent an investor collective wherein the energy generated by a collectively owned renewable energy system is apportioned among entities such as the proprietors of individual apartments (Poshnath et al., 2023). The investment decision often depends on the perception that it would be economically beneficial (reducing expenses and protecting from future high electricity prices) to install PV (e.g., Kumar et al., 2024; Reindl and Palm, 2021).

Public organizations (public property owners) own different types of municipal buildings such as schools, retirement homes and sport centers. Investment in RETs has been promoted from a policy perspective to improve energy efficient and use of renewables in public buildings (e.g., D'Agostino et al., 2017). With programs supporting energy efficiency or reduction, public organizations have been encouraged to invest in for example RETs, such as in Sweden with the first subsidy program for energy efficiency in public premises (see section 2).

In both these contexts, administrative or organizational impediments associated with collective incentives and challenges in e.g., apportioning PV installation expenses among tenants may create barriers to invest (Reindl and Palm, 2021). Challenges in attaining a collective consensus encompass physical limitations, policy, and financial constraints, as well as a deficiency in comprehension regarding renewable energy (Poshnath et al., 2023). In their study of Swedish non-residential investors in solar PV (both private owned housing companies and public property owners), Reindl and Palm (2021) found lack of subsidies as a barrier to invest in PV systems. Their empirical results show the importance for these investors to reduce pay-back time, including taking into consideration technology price and available subsidies. Subsidies were further found as an enabler for investment decision. Accordingly, we propose the following hypotheses:

H3. The subsidy level has a positive relationship with the willingness to invest in solar PV for associations.

H4. The subsidy level has a positive relationship with the willingness to invest in solar PV for public organizations.

4. Data and method

The data primarily used for the study was based on data for the subsidy program explain in Section 2. This dataset includes information about subsidy applications for investments in solar PV systems (e.g., size of PV system, installation costs, etc.).[1] The data were collected by the County Administrative Board for approval decisions, and were handled by the Swedish Board of Housing, Building and Planning, which oversaw the database. It covers applications from various investor groups in Sweden, thereby providing an overview of a majority of all PV installations (Palm and Lantz, 2020). The data was provided by the Swedish Energy Agency in a spreadsheet and include all applications from 2009 to 2021 (i.e., the period of the subsidy program), in total 79,336 applications. It includes both applications that were approved for grant and those that were not. For the study, these were all of interest as they collectively provide an overview of the number of (potential) investors of PV, thereby enabling an assessment of the effectiveness of the subsidy program in accelerating the diffusion of this technology. We focused on the registration dates of the applications to examine the effect of the subsidy on willingness to invest, thereby identifying the point in time when the intention to invest was made.

In the spreadsheet, various groups of investors eligible for the grant had been categorised by the authorities. These were individuals (private households), sole proprietorship, companies (including housing associations, economic associations, limited and incorporated companies), foundations, municipalities, regions, and authorities. Some of these categories shared similarities in their decision-making processes for new investments and their financial conditions, e.g., housing associations and foundations. For this reason, these categories were grouped together under the same investor category. Moreover, for the study, we needed groups large enough to be useful for the survey. The categories of municipalities, regions and authorities had relatively few applications, so they were grouped together as 'public organizations' for the purpose of this study. The final sample were divided into four investor groups: households, companies, associations, and public organizations.

4.1. *Dependent and independent variables*

For the study, the dependent variable was the willingness to invest in solar PV. To measure the willingness to invest we used the number of applications for the capital subsidy per month for each investor group as a proxy (cf. e.g., Palm and Lantz, 2020). Since the spreadsheet data acquired from the Swedish Energy Agency only provided information on the different applications, we could not account for changes in investment behaviour over time for single investors. Instead, the unit of analysis was the month of the application, similar to all investor groups, in order to measure effects of the subsidy on the number of applications over time for different investor groups. Thus, the willingness to invest in PV for a certain investor group was measured as the application frequency per month for that group.

The seven independent variables (IVs), one research variable and six

---

[1] When applying for the capital subsidy, applications needed to consist of information about the location of the project as well as information about the applicant such as address and contact details, when the project was intended to begin and be completed, description of the project (e.g., type of solar PV system, if the system would be connected to the grid, the combined estimated rated power of the solar modules in kilowatts, and placement of the system). It should be noted that only systems connected to the grid could be granted financial support. Finally, the applications needed to consist of calculations of costs for the solar PV modules, material for the installation, costs of labour and project planning as well as possible deductions such as insurance compensation. In total, a project could only be granted up to a maximum of 37,000 SEK/kW (approx. 3300 euro/kW), however the maximum support was allowed to amount to SEK 1.2 million per system (approx. €108,000) regardless of whether the support constituted e.g., 20% (for support level over time, see Table 1 in section 2). Eligible costs consisted of project costs, costs for materials such as solar cell modules and labour costs (provided that the person who carried out the measures was approved for notice of tax assessment for self-employed persons).

control variables, included in the study were the subsidy level, the PV module price, the serial number of the month, the electricity day-ahead spot price, the interest rate, the state of the economy, and energy tax on self-consumed electricity. Monthly measures were consequently used for all variables and the overall study period consists of 133 months, which correspond to the length of the subsidy program (see section 2). The dataset was trimmed to 130 periods because the first month was considered an outlier with a pent-up need for applications, and the last two months were also considered outliers due to the announcement that the subsidy would be discontinued. Hence, these three months were excluded from the analysis.

The first three IVs were subsidy level, PV module price, and time, which are integral to understanding the dynamics of the PV market. The subsidy level served as the primary research variable (see section 2 for further details). Detailed information on the subsidy levels was collected through a combination of governmental reports and official documentation. The subsidy level represents the extent of financial support provided to incentivize applications. As indicated by the hypotheses, this variable was considered key in exploring its impact on the number of applications. For graphic illustration of the subsidy level see Fig. A.1 in Appendix A.

PV module price during the study period referred to the monthly PV module spot price data for EU and was acquired from PVInsight (2022). The rationale for including the PV module price as an IV was its assumed positive relationship with the number of applications. A lower module price is generally associated with lower total system cost, increased affordability, and in the end profitability, which may lead to a higher number of applications.

Furthermore, we can assume the diffusion curve to match an increasing number of applications over time as the acceptance of the technology increases over time, including peer effects (e.g., Bollinger and Gillingham, 2012; Chadwick et al., 2022; Mundaca and Samahita, 2020; Palm, 2017). To account for such temporal effect related to innovation diffusion (Rogers., 2003), the time was included as a control variable: the serial number of the month. The variable represents the sequential order of the months during the study period.

Conversely, we anticipated inherent collinearity between module price and time. This expectation arises from the prospect that a novel technology, experiencing widespread adoption, will undergo a reduction in price attributed to economies of scale (Andersson and Jacobsson, 2000). Notably, built-in collinearity exists between module price and subsidies, further facilitating this developmental process (e.g., Andersson and Jacobsson, 2000). Subsidies can directly influence module prices by incentivizing demand and driving economies of scale in production, thus reinforcing the downward trajectory of prices over time.

Furthermore, it is important to address the issue of endogeneity and simultaneity inherent in our model, which complicates the interpretation of relationships among these variables. Endogeneity arises from the potential bidirectional causality between variables, whereby changes in one variable may simultaneously influence changes in another. For instance, while higher subsidy levels may stimulate greater demand for PV installations, increased demand could prompt policymakers to adjust subsidy levels. Similarly, market responses to technological advancements and changes in demand may affect both module prices and subsidy levels simultaneously.

The next IV, the electricity price, was derived from average monthly prices obtained from The Swedish Consumer Energy Markets Bureau (2023). Until October 2011, Sweden was considered one single market in terms of how the spot prices were set. From November 2011, the Swedish electricity market was divided into four separate geographical areas, each with its own price. The monthly Noord pool day-ahead spot electricity price was calculated as a volume-weighted average based on the average consumption in these different areas, in order to reflect what an approximate single market price in Sweden would have been (Janke and Steinke, 2019). The inclusion of electricity price as an IV aimed to capture its potential impact on the number of applications. A higher electricity price can be expected to have a positive relationship with the number of applications; thus, electricity price was also used as a control variable in the analysis.

The fifth IV, the interest rate, was sourced from Ekonomifakta (2023). In Sweden, the interest rate is controlled by the Riksbank, which is Sweden's central bank, and is used to either increase or decrease the general demand in the economy. The interest rate has a substantial impact on the levelized cost of electricity for large scale (Lindahl et al., 2022) and small-scale decentralized PV in Sweden (Zainali et al., 2023), and hence the profitability of an PV investment. In addition, it can also be assumed to affect the purchasing power of investors and therefore also affect the number of applications.

In addition to the interest rate, we included the state of the economy as a sixth IV. This variable serves as a measure of the purchasing power of households and companies. It can be assumed to impact the ability to invest in solar PV, and hence to impact the number of applications. Data on state of the economy were obtained from the Economic Tendency Survey compiled by the Swedish National Institute of Economic Research (NIER) (Konjunkturinstitutet, 2023). NIER is a government agency operating under the Ministry of Finance, performing analyses and forecasts of the Swedish and international economy as a basis for economic policy in Sweden. The Economic Tendency Survey is released monthly by the NIER and consists of companies' and households' survey responses about their perspective on their own- and the Swedish economy.

The IVs representing monetary values were not deflated as comparable prices since the inflation was low and rather stable over the time period of the study (Statistics Sweden, 2023).

Finally, to account for other policies in place at the same time as the subsidy program that could have had an impact on investment decisions, we also controlled for energy tax on self-consumption. The energy tax on self-consumption of electricity was included in the model as it can be assumed to have influenced investment decisions for investors e.g., aiming for maximizing installed capacity, and to affect the willingness to invest as the incentives to produce electricity for self-consumption have increased over time. Due to similarities in the legislation over the years, but with adjustments in power limit, the energy tax legislation could not be measured using a continuous variable and was instead measured using two binary variables (i.e., as policy periods). The policy periods were based on the legislations regarding energy taxes on self-consumption (based on IEA, 2018, 2022a). Table A.1 in appendix A presents the three policy periods.[2]

4.2. Data analysis

Given the count nature of the dependent variable (number of applications per month), quasi-Poisson regression was chosen as the main statistical method for this study (Ver Hoef and Boveng, 2007). Initially, regular Poisson regression was considered, but it was abandoned due to an observed overdispersion in the data. Overdispersion occurs when the variance of the dependent variable is greater than the mean, violating the assumption of equidispersion in a Poisson model. Quasi-Poisson regression was deemed appropriate as it accounts for overdispersion, allowing for the additional variability observed in the data. The quasi-Poisson model inherently adjusts for overdispersion by introducing a dispersion parameter, which effectively scales the standard errors to account for the extra-Poisson variation observed in the data. This

---

[2] For households, tax deduction (i.e., ROT tax deduction) for hiring a company for repairs, maintenance and remodelling and extensions, existed over the study period for which they could get a tax deduction for parts of the labour cost for e.g., installing solar PVs. This deduction was constant for the years before 2009 and is still active after the subsidy program has ended. Thus, it is not included in the policy packages. From January 1st, 2021 (when the subsidy program had ended for households) a similar tax reduction (i.e., the tax reduction program for green technology) is available for households where PV installations are offered a 20% deduction.

adjustment is a key feature of the quasi-Poisson approach, making it robust to overdispersion and reducing the risk of underestimating standard errors, which is a critical concern in count data regression models.

Similar to Quasi-Poisson regression, negative binomial regression is suitable for analyzing overdispersed count data (Juarez-Colunga and Dean, 2020). While both methods provide comprehensive analyses that consider varying levels of overdispersion and model assumptions, Quasi-Poisson regression was preferred due to potential advantages over negative binomial regression. Notably, Quasi-Poisson regression avoids assigning disproportionately greater weight to smaller counts, a characteristic present in negative binomial regression (Ver Hoef and Boveng, 2007).

To estimate the parameters of our quasi-Poisson regression models, we employ the quasi-likelihood approach. This method does not assume a specific distribution for the response variable but recognizes the overdispersion by allowing the variance to be a function of the mean. Specifically, the model formulates the mean of the dependent variable, Y, as a logarithmic function of the independent variables, X, linked through coefficients (β):

$$log(\mu_i) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X_{ip}$$

where μ_i is the expected mean of Y_i, and β_j are the coefficients. The variance of Y_i is assumed to be $\phi \mu_i$, with ϕ indicating the dispersion parameter.

Parameter estimation is performed by minimizing the quasi-likelihood function, which for the quasi-Poisson model, involves iteratively refining the coefficients (β) to reduce the difference between the observed and predicted values, adjusted for overdispersion. The optimization was achieved through Iteratively Reweighted Least Squares (IRLS).

Because some variables differ across households, companies, associations, and public organizations, the quasi-Poisson regression analysis was conducted separately for the four groups. Each regression model included the aforementioned independent variables (i.e., subsidy level, PV module price, electricity price, interest rate, state of the economy, binary variables representing policy periods, and serial number of the month) to examine their respective impacts on the number of applications per month.

4.3. Robustness tests

As mentioned above, the core of our analysis was based on quasi-Poisson regression models, which are adept at handling count data, such as the number of applications per month. This method is particularly suitable for our study because it accounts for the variability in the data, allowing for a mean-variance relationship that is not constant, a common scenario in count data related to policy uptake or subsidy applications, as well as overdispersion (Ver Hoef and Boveng, 2007). To ensure the robustness and validity of our findings, we complemented this primary method with a suite of supplementary analytical techniques (c.f. Provaty et al., 2024), each chosen for its specific capacity to address potential methodological challenges and to enrich the interpretation of the data.

Firstly, ridge regression was utilized as a robustness check due to the anticipated high degree of multicollinearity among three key independent variables: Subsidy Level, Month, and PV Module Price. Multicollinearity can inflate the variance of the coefficient estimates and make the model sensitive to minor changes in the model or the data, leading to unstable estimates. Ridge regression addresses this issue by introducing a penalty term to the regression coefficients, shrinking them towards zero (Hoerl and Kennard, 2000; Kennedy, 2003). This penalization method not only helps in managing multicollinearity but also improves the model's generalizability.

Secondly, to further address the endogeneity issues arising from the simultaneity among the three variables mentioned above, we adopted a two-step approach based on clustering and renewed quasi-Poisson regression. First, we clustered these variables into a single factor, conceptualized as a Market Dynamics Index (MDIndex), to capture the intertwined effects of subsidy levels, timing, and PV module prices on the subsidy application process. This clustering helped in mitigating the endogeneity problem by reducing the dimensionality of the independent variables and summarizing the complex interrelations into a comprehensive index. Subsequently, we re-analyzed the data using quasi-Poisson regression with this newly formed index, thereby refining our understanding of how market dynamics influence subsidy applications.

Thirdly, given the count nature of our dependent variable and the presence of overdispersion, negative binomial regression served as an alternative robustness check to the quasi-Poisson regression. This method extended the Poisson model by introducing an extra parameter to account for overdispersion, thereby providing more flexible and accurate estimation of count data where the regular Poisson assumption of equal mean and variance does not hold (Juarez-Colunga and Dean, 2020).

Fourthly, to achieve an integrated analysis that enhances the comparability across the four actor types, we employed Structural Equation Modeling (Fisher et al., 2014). SEM allows for the simultaneous analysis of multiple dependent variables and the intricate relationships among them, thereby offering a holistic view of the factors influencing subsidy applications across different actors. Given that our dependent variables are frequencies, we transformed them using the natural logarithm to adjust for the skewness and to meet the normality assumptions inherent in SEM.

Together, these methods formed a robust analytical framework that not only addressed the peculiarities of our data but also enhanced the reliability and validity of our findings. By employing these diverse yet complementary approaches, we ensured that our analysis remained grounded and resilient against potential methodological pitfalls, thus providing a comprehensive and nuanced understanding of the dynamics influencing subsidy applications.

5. Results

Table 2 presents the descriptive statistics for the dataset. As indicated, the standard deviations for the number of applications are high, illustrating the overdispersion in these data.

Table 3 presents the total number of applications per investor type and year during the study period.

Table 4 presents average PV module prices, interest rates, state of the economy, and electricity prices per year during the study period. For more details on the monthly changes in these variables see Fig. A.2-A.4 in Appendix A.

As mentioned above, quasi-Poisson regression analysis was

Table 2
Descriptive statistics for the dataset.

Variable	N	Mean	Median	S.D.
Number of applications households	130	391	143	533
Number of applications companies	130	109	59.0	122
Number of applications public organizations	130	7.35	5.00	7.84
Number of applications associations	130	26.6	23.0	24.8
Subsidy level households (%)	130	35.1	32.5	15.2
Subsidy level companies (%)	130	37.8	32.5	12.9
Subsidy level public organizations (%)	130	35.1	32.5	15.2
Subsidy level associations (%)	130	35.1	32.5	15.2
Electricity price (SEK per 100 kWh)	130	34.9	32.0	13.0
Month	130	66.5	66.5	37.7
State of the economy	130	102	102	8.34
Interest rate	130	0.303	0.0400	0.796
PV module price (USD per Wp)	130	0.778	0.684	0.534
Policy period 1	130	0.638	1.00	0.482
Policy period 2	130	0.0923	0.00	0.291

Table 3
Total number of applications per investor type and year.

Year	Households	Companies	Associations	Public organizations
2009	243	78	34	70
2010	346	138	60	26
2011	542	126	50	42
2012	991	176	171	31
2013	1752	404	338	95
2014	1714	665	271	52
2015	1267	856	221	96
2016	2133	1270	214	61
2017	3510	1866	464	96
2018	14,171	3786	628	238
2019	16,757	3269	693	146
2020	14,018	4241	706	112

Table 4
PV module prices, interest rates, state of the economy and electricity prices (average per year).

Year	PV module prices (USD per Wp)	Interest rate	State of the economy	Electricity price (SEK per 100 kWh)
2009	2.18	0.67	82.24	39.28
2010	1.82	0.50	108.92	54.48
2011	1.35	1.75	103.73	43.24
2012	0.83	1.45	93.50	28.43
2013	0.77	0.99	95.76	34.08
2014	0.72	0.47	101.73	28.74
2015	0.62	−0.25	103.13	20.47
2016	0.51	−0.49	104.39	27.69
2017	0.38	−0.50	110.24	30.14
2018	0.30	−0.50	108.45	46.05
2019	0.22	−0.26	98.28	40.73
2020	0.18	−0.01	86.90	19.77

employed to examine the relationship between the number of applications per month and the independent variables for households, companies, associations, and public organizations, respectively. Tables 5–8 present the results for each regression model, including relevant validity and reliability measures.

The subsidy level has a significantly positive relationship with the number of applications per month for households (odds ratio = 1.037, p < 0.001) and for companies (odds ratio = 1.033, p = 0.007). This indicates that as the subsidy level increases by one percentage point, the number of applications per month among households and companies increases on average by 3.7% and 3.3%, respectively, ceteris paribus. The odds ratio for each one of the other two investor types are not statistically significant. Thus, research hypotheses H1 and H2 were supported, but research hypotheses H3 and H4 were not supported.

The electricity price has a significantly positive relationship with the number of applications per month for households and associations. Specifically, for households, the odds ratio is 1.009 ($p = 0.002$); and for associations, the odds ratio is 1.013 ($p = 0.030$). These findings indicate that as the serial number of the month increases, the number of applications per month from households and companies increases, ceteris paribus. The odds ratio for each one of the other two investor types are not statistically significant.

The serial number of the month has a significantly positive relationship with the number of applications per month for households and companies. Specifically, for households, the odds ratio is 1.044 ($p <$ 0.001); and for companies, the odds ratio is 1.036 (p < 0.001). These findings indicate that as the serial number of the month increases, the number of applications per month from households and companies increases, ceteris paribus. The odds ratio for each one of the other two investor types are not statistically significant.

The interest rate has a significantly positive relationship with the number of applications per month for households and a significantly positive relationship with the number of applications per month for companies. Specifically, for households, the odds ratio is 1.298 ($p =$ 0.007); and for companies, the odds ratio is 0.777 ($p = 0.031$). These findings indicate that as the interest rate decreases, the number of applications per month from households decreases while the number of applications per month from companies increases, ceteris paribus. The odds ratio for each one of the other two investor types are not statistically significant.

The PV module price has a significantly negative relationship with the number of applications per month for households, public organizations, and associations. Specifically, for households, the odds ratio is 0.421 ($p = 0.005$); for public organizations, the odds ratio is 0.286 ($p =$ 0.049); and for associations, the odds ratio is 0.179 (p < 0.001). These findings indicate that as the PV module price decreases, the number of applications per month from households, public organizations, and associations increases, ceteris paribus. The odds ratio for companies are not statistically significant.

Neither the state of the economy nor the policy periods have a significantly positive relationship with the number of applications per month for any investor type.

As shown in Tables 4–7, several predictors are characterized by high VIF values, suggesting that multicollinearity could have an impact on these results. Therefore, four different robustness tests were conducted to assess if the results remained consistent across different modeling approaches (as mentioned in the methods section). The detailed results from these tests can be found in Appendices B-E. In summary, they show that the results from the quasi-Poisson regressions presented above can be considered robust for all four investor types, with the exception of the relationship between the interest rate and the number of applications per month for households, the relationship between the electricity price and the number of applications per month for companies, and potentially also the relationship between the subsidy level and the number of applications per month for companies.

Table 5
Regression results for households.

				95% exp.(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	p	VIF
(Intercept)	5.115***	0.047	166.474	151.24	182.171	< 0.001	
Subsidy level	0.036***	0.007	1.037	1.024	1.051	< 0.001	17.70
Electricity price	0.009**	0.003	1.009	1.004	1.015	0.002	2.22
Month	0.043***	0.005	1.044	1.035	1.054	< 0.001	39.46
State of the economy	0.005	0.003	1.005	0.998	1.011	0.184	1.45
Interest rate	0.261**	0.096	1.298	1.076	1.566	0.007	6.06
PV module price	−0.866**	0.302	0.421	0.229	0.749	0.005	19.74
Policy period 1	0.232	0.190	1.261	0.869	1.835	0.225	11.22
Policy period 2	−0.121	0.146	0.886	0.665	1.180	0.410	2.67
R-squared	0.961						
Chi-squared/DF	25.061						

Table 6
Regression results for companies.

				95% exp.(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	p	VIF
(Intercept)	4.024***	0.056	55.947	49.902	62.232	< 0.001	
Subsidy level	0.033**	0.012	1.033	1.009	1.058	0.007	20.02
Electricity price	0.004	0.003	1.004	0.997	1.011	0.265	2.03
Month	0.035***	0.007	1.036	1.022	1.049	< 0.001	42.80
State of the economy	0.009	0.005	1.010	1.000	1.020	0.065	1.64
Interest rate	−0.252*	0.116	0.777	0.619	0.973	0.031	4.80
PV module price	−0.667	0.372	0.513	0.243	1.049	0.075	20.34
Policy period 1	0.363	0.213	1.438	0.947	2.185	0.091	10.59
Policy period 2	−0.030	0.146	0.970	0.728	1.292	0.838	2.21
R-squared	0.913						
Chi-squared/DF	12.146						

Table 7
Regression results for public organizations.

				95% exp.(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	p	VIF
(Intercept)	1.805***	0.085	6.080	5.110	7.144	< 0.001	
Subsidy level	0.028	0.020	1.029	0.990	1.070	0.152	17.70
Electricity price	0.008	0.009	1.008	0.990	1.026	0.361	2.22
Month	0.008	0.013	1.008	0.984	1.034	0.504	39.46
State of the economy	0.001	0.012	1.001	0.979	1.025	0.917	1.45
Interest rate	−0.356	0.260	0.701	0.418	1.164	0.174	6.06
PV module price	−1.251*	0.628	0.286	0.083	0.973	0.049	19.74
Policy period 1	0.347	0.488	1.414	0.554	3.762	0.479	11.22
Policy period 2	−0.302	0.407	0.740	0.332	1.647	0.461	2.67
R-squared	0.414						
Chi-squared/DF	4.829						

Table 8
Regression results for associations.

				95% exp.(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	p	VIF
(Intercept)	2.932***	0.069	18.773	16.277	21.357	< 0.001	
Subsidy level	0.011	0.013	1.011	0.986	1.036	0.411	17.70
Electricity price	0.013*	0.006	1.013	1.001	1.025	0.030	2.22
Month	0.014	0.008	1.014	0.997	1.030	0.102	39.46
State of the economy	−0.001	0.007	1.000	0.985	1.015	0.958	1.45
Interest rate	0.141	0.180	1.151	0.810	1.640	0.434	6.06
PV module price	−1.723***	0.462	0.179	0.070	0.433	< 0.001	19.74
Policy period 1	0.526	0.331	1.691	0.892	3.276	0.116	11.22
Policy period 2	0.155	0.256	1.168	0.710	1.937	0.545	2.67
R-squared	0.687						
Chi-squared/DF	6.960						

6. Discussion and concluding remarks

The aim of this paper was to analyse the relationship between policy incentives and the willingness to invest for different types of investors, including households, companies, associations, and public organizations. Based on extensive data on RET adopters in Sweden for the period 2009 to 2020, the impact of incentive levels on the willingness of various actors to invest in RET over time was examined. To account for other factors influencing the willingness to invest, the paper also examined the impact of the PV module price, the electricity price, the interest rate, the state of the economy, energy tax for self-consumed electricity, and time.

Our results reveal that there were important disparities among the four different groups, which suggests that different factors of market dynamics may impact RET investor groups differently. In particular, only households had a significantly positive relationship between the subsidy level and the willingness to invest. A similar effect was observed for private companies, although, the robustness of this relationship may be questioned due to potential instability (see Limitations section). For the other two RET investor groups, i.e., associations and public organizations, there was no significant relationship between the level of subsidies and the willingness to invest. This is interesting from a policy perspective, as it indicates that households and companies are more sensitive to economic incentives in the form of subsidies than the other groups of investors. To some extent, in line with previous studies (e.g. De Groote and Verboven, 2019), it shows that households react more to incentives facilitating the investment upfront, particularly electricity prices and price of the technology, than incentives increasing the profitability of the investment over time. Likewise, it confirms that companies behave as professional investors and are more economically rational (Karneyeva and Wüstenhagen, 2017), as a positive relationship was found between interest rates, subsidy levels, and their willingness to invest. In contrast to the private companies and households, public organizations and associations do not appear to be more willing to invest when the subsidy level is higher. One explanation for that is, in line with e.g., Criscuolo and Menon (2015); Polzin (2017); Polzin et al. (2015), that the policy risk (in our case, the limited budget of the Swedish subsidy program, the long waiting time for subsidies and the frequent changes in the level of the subsidies) has had a negative influence on public organizations and associations. This suggests that public organizations and associations can be considered as more sensitive to policy risks than other RET investors, and that faced with such risks, they are more keen to react with a wait-and-see strategy.

While a significant relationship between interest rate and willingness to invest was found for companies, such a relationship could not be established for households. A possible explanation could be that both interest rates and electricity prices were historically low during the study period. Nevertheless, rates and prices have changed drastically since 2020, especially under the European energy crises in 2022 following the Russian invasion of Ukraine, and it is likely that more recent data could yield different outcomes. This opens the door for future research to include the years after the subsidy program ended to capture a broader picture of the influence of different variables of the willingness to invest for different investor groups.

Overall, although a combination of market dynamic factors impact on the willingness to invest in solar PVs, the disparities between the investor groups in our study confirm the importance of considering investors' heterogeneity when it comes to designing policies (Bergek and Mignon, 2017; Karneyeva and Wüstenhagen, 2017; Mignon and Bergek, 2016a). Given the significant impact of the subsidy level on households, it is clear that the subsidy program has contributed to induce investment in this particular group, while the impact on other investor groups remains statistically unclear. In a context where investments in technologies contributing to the transition to a sustainable energy system are more urgent than ever, there is a need to find strategies to accelerate such diffusion process (Mignon, 2016). Our results clearly show that incentive subsidies are a way to accelerate investments among households and private companies (with some reservations due to potential endogeneity, see Limitation section), but there is a need to find other or additional strategies for other investor groups. This statement goes in line with what has been stated many times in the energy policy literature, namely that one size does not fit all when it comes to incentive policies aiming at inducing investments in RETs (Fouquet, 2013; Pitelis et al., 2020). This also emphasizes the need for research to better inform policymakers about investor groups' potential preferences. Based on the results of this study, we suggest that in order to capture the nuances among different investor groups, this should not only focus on extreme or oppositive groups, e.g., companies versus households (Best et al., 2023; Kopsakangas-Savolainen et al., 2017; Poier, 2021), or revenue-driven versus saving-driven actors (e.g. Karneyeva and Wüstenhagen, 2017) but also for other subgroups, such as households, companies, associations and public organizations.

7. Limitations and future research

While this study provides insights into the impact of subsidy levels on the willingness to invest in RETs in Sweden, it is important to acknowledge the inherent complexity and limitation of endogeneity between the market dynamic variables, such as module price, time, and subsidy level. Specifically, the potential for endogeneity poses a significant challenge. This bias arises because the causality between variables may be bidirectional; for instance, while higher subsidies may stimulate more applications, an increase in applications could influence adjustments to subsidy levels. Similarly, market responses to technology demand impact technology prices, which, in turn, may be influenced by application frequency. The variable of time further complicates matters by encapsulating evolving, unobserved factors that affect both policy decisions and market dynamics. Despite our efforts to control for observable factors and employ rigorous statistical techniques and robustness analyses, complete elimination of bias remains elusive. Nonetheless, our robustness tests suggest that the results from the quasi-Poisson regressions are resilient across all four investor types. Specifically, the MDIndex (Appendix C) indicates that market dynamics, as reflected by the combined effect of endogenous independent variables, positively influence investment willingness for all investor groups.

We further acknowledge the inherent multicollinearity among the three market dynamics variables (see Method section). As presented in Section 2, throughout the subsidy program period, reductions in the support level were implemented to align with the evolving technology prices. However, despite a significant decline in PV module prices from 2009 to 2013, the subsidy level remained relatively high compared to the ongoing price trend. While, in the early stages, government interventions, including subsidies, play a crucial role in enhancing diffusion, policy interventions should be balanced, e.g., to prevent market disruptions avoid market overcapacity and ensure the sustainability of actors. Therefore, subsidy levels should align with the decreasing technology prices over time. Nonetheless, the long-term consequences of these dynamics on the solar PV market in Sweden may warrant further investigation.

Moreover, the country-specific nature of the data also serves as a limitation, potentially restricting the generalizability of the findings to other countries. Future research could benefit from cross-country comparisons to assess how different policy, economic, and cultural contexts influence investor behaviour in the renewable energy sector.

Additionally, as the study focus on each investor group separately, instead of comparing the outcomes of each of the four models, future research could benefit from looking into the relation between groups using other types of data. Addressing these limitations could further enhance our understanding of the factors driving investment decisions in renewable energy technologies.

CRediT authorship contribution statement

Hanna Rydehell: Writing – review & editing, Writing – original draft, Visualization, Methodology, Data curation, Conceptualization. **Björn Lantz:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Ingrid Mignon:** Writing – original draft, Project administration, Funding acquisition, Data curation, Conceptualization, Writing – review & editing. **Johan Lindahl:** Writing – original draft, Validation, Conceptualization.

Declaration of competing interest

none.

Appendix A. Graphical illustrations and information on independent variables

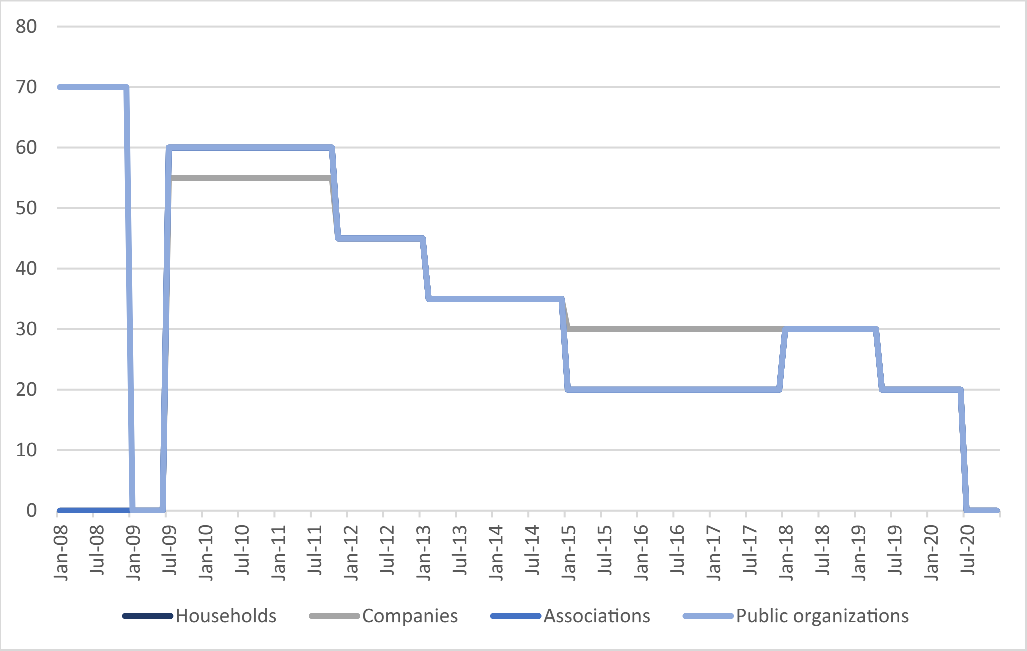

Fig. A.1. Subsidy level (%) from the energy efficiency improvements in public premises 2008–2009 to the support for solar PV for all investor groups 2009–2021.

Table A.1
Summary of the current and historical practical consequences of the Swedish legislations on Energy Tax.

Policy period 1	Policy period 2	Policy period 3
Before 2016-07-01 A PV electricity producer did not have to pay any energy tax for the self-consumed electricity if; - the producer did not have other electricity production facilities that together had an installed capacity of 100 kW$_p$ or more, - did not professionally deliver any other electricity to other consumers - and the compensation for the excess electricity did not exceed 30,000 SEK in a calendar year	2016-07-01 to 2017-07-01 A PV electricity producer did not have to pay any energy tax for the self-consumed electricity if; - the PV system capacity was below 255 kW$_p$, - and the producer controlled a total installed PV capacity power output of <255 kW$_p$, - and electric power had not been transferred to an electricity grid covered by a grid concession	From 2017 to 07-01 to 2021-07-01 A PV electricity producer that owned one or more PV systems whose total power amounted to <255 kW$_p$ did not have to pay any energy tax for the self-consumed electricity consumed within the same premises as where the PV systems were installed.
	A solar producer that owned several PV systems, which total power amounted to 255 kW$_p$ or more, but where all the individual PV systems were smaller than 255 kW$_p$, paid an energy tax of 0.005 SEK/kWh on the self-consumed electricity used within the same premises as where the PV systems were installed. A solar producer that owned a PV system larger than 255 kW$_p$ paid the normal energy tax of on the self-consumed electricity used within the same premises as where the PV systems were installed, but 0.005 SEK/kWh in energy tax for the self-consumed electricity from the other systems if they had a capacity <255 kW$_p$.	A PV electricity producer that owns several PV systems, which total power amounts to 500 kW$_p$ or more, but where all the individual PV systems are smaller than 500 kW$_p$, pays an energy tax of 0.005 SEK/kWh on the self-consumed electricity used within the same premises as where the PV systems is installed. A PV electricity producer that owns a PV system larger than 500 kW$_p$ pays the normal energy tax of on the self-consumed electricity used within the same premises as where the PV systems is installed, but 0.005 SEK/kWh in energy tax for the self-consumed electricity from the other systems if they have a capacity <500 kW$_p$.

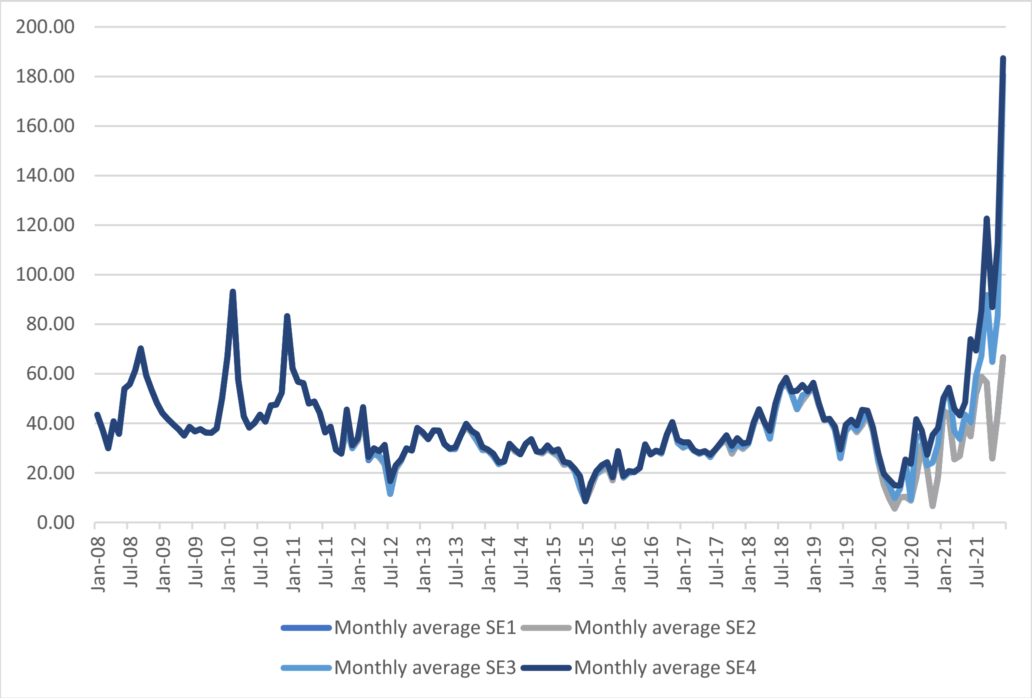

Fig. A.2. Spot electricity prices, monthly average value for electricity areas in Sweden (SEK per 100 kWh) (The Swedish Consumer Energy Markets Bureau, 2023).

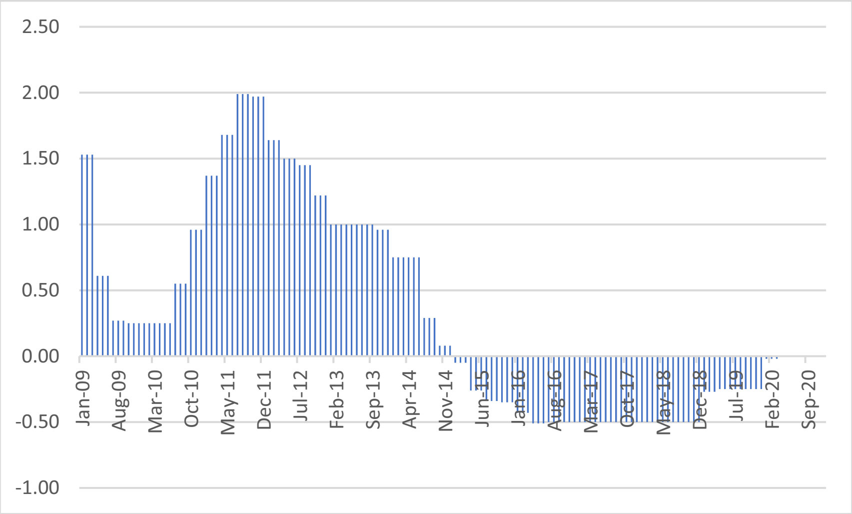

Fig. A.3. Interest rates in Sweden on monthly basis (Ekonomifakta, 2023).

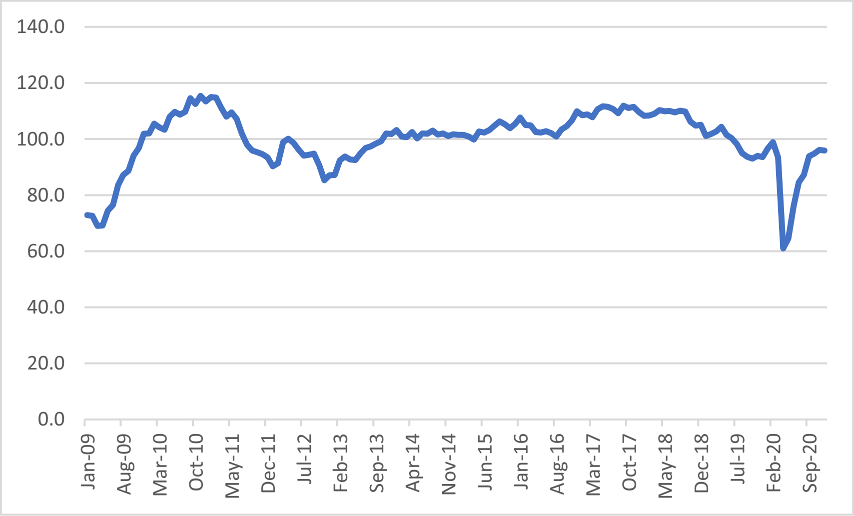

Fig. A.4. Economic cycle in Sweden (state of the economy) on monthly basis (Konjunkturinstitutet, 2023).

Appendix B. Ridge regressions

In the context of this study, ridge regression was employed for the robustness checks to address the anticipated high degree of multicollinearity among the three principal independent variables: Subsidy Level, Month, and PV Module Price. The presence of multicollinearity in a multiple regression analysis can significantly skew the reliability of coefficient estimates. This skewness arises because multicollinearity amplifies the variance of the coefficient estimates, rendering the model unduly sensitive to minor fluctuations in the data or model specifications. Such sensitivity results in unstable estimates, potentially compromising the interpretability and validity of the model's outcomes.

Ridge regression provides a solution to these challenges by incorporating a penalty term into the least squares objective function (Hoerl and Kennard, 2000; Kennedy, 2003). This penalty, proportional to the square of the coefficient magnitudes, effectively constrains the size of the coefficients through a regularization parameter. The regularization parameter plays a pivotal role in this method, dictating the severity of the penalty imposed on the coefficients. A larger regularization parameter value results in greater shrinkage of the coefficients towards zero, which in turn reduces their variance and the risk of model overfitting. Overfitting is a critical concern in model building, as it indicates that the model is excessively complex, capturing noise rather than the underlying data pattern. By penalizing large coefficients, ridge regression mitigates the risk of overfitting, thereby enhancing the model's ability to generalize to new datasets. This regularization approach not only addresses multicollinearity but also strikes a balance between model complexity and simplicity, ensuring that the model remains robust, and its interpretations remain reliable.

The results from the ridge regression analyses appear in Tables B1-B4 below. These results show that the results from the quasi-poisson regressions seem robust for all four investor types, with the exception of the relationship between the interest rate and the number of applications per month for households. The reason for this interpretation is that the ridge regression coefficient shows a negative sign for this variable, while the coefficient was positive in the corresponding quasi-poisson regression.

Table B1
Households.

	Mean	Std. Dev.	Standardized Coefficients	Unstandardized Coefficients
(Intercept)			383.908	310.031
Subsidy level	34.540	15.548	216.257	13.909
Electricity price	34.656	12.502	106.375	8.508
Month	67.678	36.823	482.740	13.110
State of the economy	102.803	7.722	−102.789	−13.310
Interest rate	0.234	0.793	−30.625	−38.639
PV module price	0.770	0.528	−3.477	−6.583
Policy period 1	0.632	0.482	−131.738	−273.195
Policy period 2	0.092	0.289	−105.211	−364.100

Training: $N = 87$, R^2 = 0.870
Holdout: $N = 43$, R^2 = 0.866
Alpha = 2.000

Table B2
Companies.

	Mean	Std. Dev.	Standardized Coefficients	Unstandardized Coefficients
(Intercept)			97.031	22.019
Subsidy level	38.214	12.783	18.01	1.409
Electricity price	34.405	12.6	11.153	0.885
Month	64.888	35.977	73.101	2.032
State of the economy	101.832	7.722	−5.35	−0.693
Interest rate	0.319	0.794	−8.647	−10.891
PV module price	0.787	0.518	1.036	2.001
Policy period 1	0.673	0.469	−42.993	−91.68
Policy period 2	0.071	0.258	−25.003	−97.083

Training: $N = 98$, Rˆ2 = 0.880
Holdout: $N = 32$, Rˆ2 = 0.639
Alpha = 2.000

Table B3
Public organizations.

	Mean	Std. Dev.	Standardized Coefficients	Unstandardized Coefficients
(Intercept)			7.217	−6.573
Subsidy level	35.109	14.54	2.432	0.167
Electricity price	34.683	11.972	1.26	0.105
Month	66.217	35.361	1.993	0.056
State of the economy	102.868	6.735	0.413	0.061
Interest rate	0.292	0.807	−1.896	−2.349
PV module price	0.764	0.504	−3.311	−6.569
Policy period 1	0.641	0.48	0.282	0.589
Policy period 2	0.109	0.311	−1.272	−4.088

Training: N = 98, Rˆ2 = 0.302
Holdout: N = 32, Rˆ2 = 0.430
Alpha = 2.000

Table B4
Associations.

	Mean	Std. Dev.	Standardized Coefficients	Unstandardized Coefficients
(Intercept)			25.214	20.502
Subsidy level	35.765	15.801	5.388	0.341
Electricity price	35.452	13.498	1.839	0.136
Month	65.092	38.22	12.297	0.322
State of the economy	102.503	7.615	−1.322	−0.174
Interest rate	0.288	0.792	−2.114	−2.669
PV module price	0.817	0.559	−6.535	−11.684
Policy period 1	0.653	0.476	−3.214	−6.752
Policy period 2	0.082	0.274	−2.475	−9.039

Training: N = 98, Rˆ2 = 0.563
Holdout: N = 32, Rˆ2 = 0.534
Alpha = 2.000

Appendix C. Market dynamics

Due to the intrinsic relationship and multicollinearity among the three variables Subsidy Level, Month, and PV Module Price previously discussed, this appendix further investigates endogeneity issues in the regression model as part of the robustness analysis. To address this, we cluster these independent variables into a single factor named MDIndex (Market Dynamics Index), which is derived from their z-scores, prior to re-estimating the quasi-Poisson regressions. The findings of these analyses are presented in Tables C1-C4. Specifically, the MDIndex is computed by adding the z-score of the Subsidy Level for the actor type and the z-score of the Month, then subtracting the z-score of the PV Module Price level. This calculation is based on the premise that higher values of the first two variables and lower values of the third are likely to positively influence the number of applications. Typically, high correlation among independent variables in a regression model can cause unstable regression coefficient estimates, complicating the interpretation of each variable's individual effects. By combining these variables into a single factor, the model's dimensionality is decreased. This newly created factor captures the common variance among these variables, potentially yielding more stable and interpretable outcomes.

The results, as illustrated in Tables C1-C4, indicate that the MDIndex is significantly positively associated with the number of applications across all four actor types. In essence, stronger market dynamics—reflected by the combined effect of a higher subsidy level, a later month within the observed period, and a lower PV module price—appear to positively influence the number of applications for each actor type. Notably, and central to our main analysis, different elements of the market dynamics factor appear to impact the various actor types in distinct ways.

Table C1
Households.

Names	Estimate	SE	exp(B)	p	VIF
(Intercept)	5.148	0.051	172.085	< 0.001	
MDIndex	0.957	0.084	2.604	< 0.001	4.63
Electricity_price	−0.001	0.003	0.999	0.730	1.63
State_of_the_economy	−0.006	0.004	0.994	0.112	1.43
Interest_rate	−0.176	0.088	0.839	0.049	2.19
Policy_period_1	−0.337	0.196	0.714	0.089	7.17
Policy_period_2	−0.358	0.158	0.699	0.025	1.86

Table C2
Companies.

Names	Estimate	SE	exp(B)	p	VIF
(Intercept)	4.066	0.057	57.946	< 0.001	
MDIndex	0.836	0.109	2.307	< 0.001	4.83
State_of_the_economy	−0.004	0.004	0.996	0.328	1.46
Electricity_price	−0.002	0.003	0.998	0.614	1.84
Interest_rate	−0.571	0.103	0.565	< 0.001	2.11
Policy_period_1	−0.051	0.186	0.951	0.788	6.61
Policy_period_2	−0.306	0.133	0.736	0.023	1.60

Table C3
Public organizations.

Names	Estimate	SE	exp(B)	p	VIF
(Intercept)	1.810	0.084	6.111	< 0.001	
MDIndex	0.553	0.157	1.739	< 0.001	4.63
Electricity_price	0.006	0.007	1.006	0.430	1.63
State_of_the_economy	0.003	0.010	1.003	0.804	1.43
Interest_rate	−0.363	0.161	0.696	0.026	2.19
Policy_period_1	0.499	0.400	1.647	0.214	7.17
Policy_period_2	−0.179	0.356	0.836	0.617	1.86

Table C4
Associations.

Names	Estimate	SE	exp(B)	p	VIF
(Intercept)	3.010	0.062	20.296	< 0.001	
MDIndex	0.780	0.123	2.181	< 0.001	4.63
Electricity_price	−0.0002	0.005	1.000	0.969	1.63
State_of_the_economy	−0.004	0.007	0.996	0.585	1.43
Interest_rate	−0.246	0.113	0.782	0.031	2.19
Policy_period_1	0.632	0.291	1.882	0.032	7.17
Policy_period_2	0.346	0.237	1.414	0.147	1.86

Appendix D. Negative binomial regression

As previously mentioned, Quasi-Poisson regression and Negative Binomial regression are two methods largely seen as interchangeable for analyzing overdispersed count data. Both methods are well-suited for scenarios where the variance of the count data significantly exceeds the mean, as highlighted by Juarez-Colunga and Dean (2020). Despite their similarities, Quasi-Poisson regression possesses some potential advantages over Negative Binomial regression. Specifically, Quasi-Poisson regression avoids giving disproportionately greater weight to smaller counts, a characteristic observed in Negative Binomial regression (Ver Hoef and Boveng, 2007). This attribute of Quasi-Poisson regression helps in ensuring a more balanced analysis, especially important when smaller counts are involved.

Due to this advantage, Quasi-Poisson regression was chosen as the primary method for data analysis in our study. On the other hand, we have used Negative Binomial regression as a robustness check. This approach allows us to leverage the strengths of both methods, ensuring a comprehensive and nuanced analysis of the data. By applying Negative Binomial regression in conjunction with Quasi-Poisson, we aim to validate the robustness and reliability of our findings, ensuring that our conclusions are well-supported by the data.

The results from the Negative Binomial regression analyses appear in Tables D1-D4 below. The noteworthy differences compared to the Quasi-Poisson regressions are that Interest rate is not statistically significant for households, that the Subsidy level is not statistically significant for companies, that the Electricity price is significantly positively related to the number of applications for companies, and that PV module price is only marginally statistically significant for public organizations.

Table D1
Households.

				95% Exp(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	z	p
(Intercept)	5.151	0.030	172.680	162.969	183.134	173.320	< 0.001
Subsidy_level	0.032	0.008	1.033	1.016	1.050	3.956	< 0.001
Electricity_price	0.010	0.003	1.010	1.003	1.018	2.936	0.003
Month	0.035	0.005	1.036	1.026	1.046	7.224	< 0.001
State_of_the_economy	−0.011	0.004	0.989	0.980	0.998	−2.503	0.012
Interest_rate	0.057	0.094	1.059	0.884	1.270	0.611	0.541
PV_module_price	−0.761	0.246	0.467	0.294	0.743	−3.095	0.002
Policy_period_1	−0.063	0.204	0.939	0.611	1.429	−0.310	0.757
Policy_period_2	−0.269	0.163	0.764	0.544	1.068	−1.648	0.099

Table D2
Companies.

				95% Exp(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	z	p
(Intercept)	4.029	0.034	56.185	52.595	60.062	118.911	< 0.001
Subsidy_level	0.008	0.012	1.008	0.985	1.031	0.644	0.520
Electricity_price	0.009	0.004	1.009	1.002	1.017	2.486	0.013
Month	0.025	0.006	1.025	1.013	1.037	4.169	< 0.001
State_of_the_economy	0.0007	0.005	1.001	0.990	1.011	0.130	0.896
Interest_rate	−0.419	0.097	0.658	0.548	0.791	−4.330	< 0.001
PV_module_price	−0.527	0.285	0.591	0.345	1.011	−1.850	0.064
Policy_period_1	0.159	0.222	1.172	0.750	1.827	0.716	0.474
Policy_period_2	−0.139	0.163	0.870	0.629	1.203	−0.852	0.394

Table D3
Public organizations.

				95% Exp(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	z	p
(Intercept)	1.810	0.067	6.111	5.359	6.98	26.8870	< 0.001
Subsidy_level	0.019	0.018	1.019	0.982	1.06	1.0263	0.305
Electricity_price	0.009	0.008	1.009	0.993	1.03	1.1735	0.241
Month	0.010	0.011	1.010	0.988	1.03	0.8910	0.373
State_of_the_economy	−0.0005	0.010	1.000	0.981	1.02	−0.0490	0.961
Interest_rate	−0.276	0.214	0.759	0.502	1.15	−1.2883	0.198
PV_module_price	−0.949	0.551	0.387	0.133	1.12	−1.7225	0.085
Policy_period_1	0.321	0.450	1.378	0.528	3.50	0.7133	0.476
Policy_period_2	−0.340	0.365	0.712	0.338	1.48	−0.9295	0.353

Table D4
Associations.

				95% Exp(B) C.I.			
Names	Estimate	SE	exp(B)	Lower	Upper	z	p
(Intercept)	2.956	0.049	19.212	17.4760	21.145	60.9128	< 0.001
Subsidy_level	0.006	0.013	1.006	0.9810	1.032	0.4726	0.637
Electricity_price	0.017	0.006	1.017	1.0059	1.029	2.9977	0.003
Month	0.007	0.008	1.007	0.9921	1.022	0.9083	0.364
State_of_the_economy	−0.011	0.007	0.989	0.9746	1.003	−1.5934	0.111
Interest_rate	−0.144	0.156	0.866	0.6410	1.172	−0.9218	0.357
PV_module_price	−1.608	0.396	0.200	0.0954	0.418	−4.0648	< 0.001
Policy_period_1	0.380	0.322	1.462	0.7662	2.753	1.1787	0.239
Policy_period_2	−0.011	0.2576	0.989	0.6043	1.609	−0.0426	0.966

Appendix E. Structural equation modeling

In our study, Structural Equation Modeling (Fisher et al., 2014) was applied as a robustness check to simultaneously analyse the dependence of application frequencies on explanatory variables for all four actor types, using a transformation with the natural logarithm for data normalization.

SEM enables the direct modeling of relationships between multiple dependent variables and their predictors, effectively capturing how variations in explanatory variables influence application frequencies.

The results from the SEM analysis appear in Table E1. The noteworthy differences compared to the Quasi-Poisson regressions are that Interest rate is not statistically significant for households, and that the Electricity price is significantly positively related to the number of applications for companies. We can also note that the standardized estimates for the relationship between the Subsidy level and the applications frequency are almost equal for households and companies, which can be seen as an indication that a change in the subsidy level will have similar impact on the application frequency for these two actor types.

Table E1
SEM.

				95% C.I.				
Dependent	Predictor	Estimate	SE	Lower	Upper	β	z	p
Households	SubOther	0.036	0.007	0.022	0.051	0.407	4.943	< 0.001
Households	ElPrice	0.008	0.003	0.001	0.014	0.073	2.250	0.024
Households	Month_	0.038	0.005	0.029	0.048	1.079	7.667	< 0.001
Households	StateEc	−0.008	0.004	−0.017	0.000	−0.051	−1.907	0.056
Households	IntRate	0.085	0.091	−0.094	0.263	0.048	0.930	0.353
Households	PVprice	−0.704	0.251	−1.195	−0.213	−0.281	−2.810	0.005
Households	PP1	−0.026	0.201	−0.419	0.367	−0.010	−0.131	0.896
Households	PP2	−0.214	0.163	−0.533	0.105	−0.047	−1.315	0.188
Companies	SubComp	0.041	0.011	0.020	0.063	0.394	3.719	< 0.001
Companies	ElPrice	0.009	0.004	0.001	0.017	0.087	2.219	0.027
Companies	Month_	0.036	0.006	0.023	0.048	1.007	5.562	< 0.001
Companies	StateEc	−0.004	0.006	−0.015	0.007	−0.026	−0.751	0.453
Companies	IntRate	−0.476	0.102	−0.676	−0.276	−0.273	−4.664	< 0.001
Companies	PVprice	−0.721	0.313	−1.334	−0.108	−0.289	−2.306	0.021
Companies	PP1	0.513	0.243	0.036	0.990	0.186	2.108	0.035
Companies	PP2	0.055	0.188	−0.314	0.424	0.012	0.292	0.770
PublicOrganizations	SubOther	0.027	0.018	−0.009	0.062	0.415	1.482	0.138
PublicOrganizations	ElPrice	0.005	0.008	−0.010	0.020	0.063	0.614	0.539
PublicOrganizations	Month_	0.003	0.011	−0.019	0.025	0.120	0.270	0.787
PublicOrganizations	StateEc	−0.007	0.010	−0.026	0.012	−0.058	−0.692	0.489
PublicOrganizations	IntRate	−0.226	0.209	−0.637	0.184	−0.181	−1.080	0.280
PublicOrganizations	PVprice	−1.250	0.573	−2.373	−0.126	−0.697	−2.181	0.029
PublicOrganizations	PP1	−0.199	0.459	−1.099	0.701	−0.101	−0.434	0.664
PublicOrganizations	PP2	−0.402	0.372	−1.130	0.326	−0.124	−1.082	0.279
Associations	SubOther	0.009	0.013	−0.016	0.034	0.130	0.723	0.469
Associations	ElPrice	0.016	0.006	0.005	0.027	0.192	2.739	0.006
Associations	Month_	0.010	0.009	−0.006	0.027	0.365	1.205	0.228
Associations	StateEc	−0.010	0.007	−0.025	0.004	−0.079	−1.372	0.170
Associations	IntRate	−0.204	0.156	−0.509	0.102	−0.147	−1.308	0.191
Associations	PVprice	−1.441	0.429	−2.281	−0.600	−0.726	−3.360	< 0.001
Associations	PP1	0.440	0.343	−0.232	1.113	0.201	1.283	0.199
Associations	PP2	−0.149	0.279	−0.695	0.397	−0.041	−0.534	0.593

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2024.107552.

References

Agterbosch, S., Vermeulen, W., Glasbergen, P., 2004. Implementation of wind energy in the Netherlands: the importance of the social–institutional setting. Energy Policy 32 (18), 2049–2066.

Andersson, B.A., Jacobsson, S., 2000. Monitoring and assessing technology choice: the case of solar cells. Energy Policy 28 (14), 1037–1049.

Andersson, J., Hellsmark, H., Sandén, B., 2021. Photovoltaics in Sweden–Success or failure? Renew. Sust. Energ. Rev. 143, 110894.

Aydın, E., Brounen, D., Ergün, A., 2023. The rebound effect of solar panel adoption: evidence from Dutch households. Energy Econ. 120, 106645.

Barazza, E., Strachan, N., 2020. The impact of heterogeneous market players with bounded-rationality on the electricity sector low-carbon transition. Energy Policy 138, 111274.

Bergek, A., Jacobsson, S., 2010. Are tradable green certificates a cost-efficient policy driving technical change or a rent-generating machine? Lessons from Sweden 2003–2008. Energy Policy 38 (3), 1255–1271.

Bergek, A., Mignon, I., 2017. Motives to adopt renewable electricity technologies: evidence from Sweden. Energy Policy 106, 547–559.

Bergek, A., Mignon, I., Sundberg, G., 2013. Who invests in renewable electricity production? Empirical evidence and suggestions for further research. Energy Policy 56, 568–581.

Best, R., 2017. Switching towards coal or renewable energy? The effects of financial capital on energy transitions. Energy Econ. 63, 75–83.

Best, R., Marrone, M., Linnenluecke, M., 2023. Meta-analysis of the role of equity dimensions in household solar panel adoption. Ecol. Econ. 206, 107754.

Bollinger, B., Gillingham, K., 2012. Peer effects in the diffusion of solar photovoltaic panels. Mark. Sci. 31 (6), 900–912.

Briguglio, M., Formosa, G., 2017. When households go solar: determinants of uptake of a photovoltaic scheme and policy insights. Energy Policy 108, 154–162.

Brudermann, T., Reinsberger, K., Orthofer, A., Kislinger, M., Posch, A., 2013. Photovoltaics in agriculture: a case study on decision making of farmers. Energy Policy 61, 96–103.

Bürer, M.J., Wüstenhagen, R., 2009. Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors. Energy Policy 37 (12), 4997–5006.

Chadwick, K., Russell-Bennett, R., Biddle, N., 2022. The role of human influences on adoption and rejection of energy technology: a systematised critical review of the literature on household energy transitions. Energy Res. Soc. Sci. 89, 102528.

Ciarreta, A., Espinosa, M.P., Pizarro-Irizar, C., 2017. Optimal regulation of renewable energy: a comparison of feed-in tariffs and tradable green certificates in the Spanish electricity system. Energy Econ. 67, 387–399.

Criscuolo, C., Menon, C., 2015. Environmental policies and risk finance in the green sector: cross-country evidence. Energy Policy 83, 38–56.

D'Agostino, D., Cuniberti, B., Bertoldi, P., 2017. Energy consumption and efficiency technology measures in European non-residential buildings. Energ. Build. 153, 72–86.

De Groote, O., Verboven, F., 2019. Subsidies and time discounting in new technology adoption: evidence from solar photovoltaic systems. Am. Econ. Rev. 109 (6), 2137–2172.

Dinica, V., 2006. Support systems for the diffusion of renewable energy technologies—an investor perspective. Energy Policy 34 (4), 461–480. http://www.sciencedirect.com/science/article/pii/S0301421504001880.

Dusonchet, L., Telaretti, E., 2015. Comparative economic analysis of support policies for solar PV in the most representative EU countries. Renew. Sust. Energ. Rev. 42, 986–998.

Ekonomifakta, 2023. Styrräntan. Ekonomifakta. https://www.ekonomifakta.se/Fakta/finansiell-ekonomi/inflation-och-styrrantor/Styrrantan/.

Finon, D., Perez, Y., 2007. The social efficiency of instruments of promotion of renewable energies: a transaction-cost perspective. Ecol. Econ. 62 (1), 77–92. https://doi.org/10.1016/j.ecolecon.2006.05.011.

Fisher, R., Maritz, A., Lobo, A., 2014. Evaluating entrepreneurs' perception of success: development of a measurement scale. Int. J. Entrep. Behav. Res. 20 (5), 478–492.

Fleiß, E., Hatzl, S., Seebauer, S., Posch, A., 2017. Money, not morale: the impact of desires and beliefs on private investment in photovoltaic citizen participation initiatives. J. Clean. Prod. 141, 920–927.

Fleten, S.-E., Maribu, K.M., Wangensteen, I., 2007. Optimal investment strategies in decentralized renewable power generation under uncertainty. Energy 32 (5), 803–815.

Fouquet, D., 2013. Policy instruments for renewable energy–from a European perspective. Renew. Energy 49, 15–18.

Frey, E.F., Mojtahedi, S., 2018. The impact of solar subsidies on California's non-residential sector. Energy Policy 122, 27–35.

García-Maroto, I., García-Maraver, A., Muñoz-Leiva, F., Zamorano, M., 2015. Consumer knowledge, information sources used and predisposition towards the adoption of wood pellets in domestic heating systems. Renew. Sust. Energ. Rev. 43, 207–215.

Gautier, A., Jacqmin, J., 2020. PV adoption: the role of distribution tariffs under net metering. J. Regul. Econ. 57, 53–73.

Government Offices of Sweden, 2009. Förordning (2009:689) om statligt stöd till solceller. Retrieved from. https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/forordning-2009689-om-statligt-stod-till_sfs-2009-689/.

Government Offices of Sweden, 2020. Skattereduktion för installation av grön teknik. Retrieved from. https://www.regeringen.se/rattsliga-dokument/lagradsremiss/2020/08/skattereduktion-for-installation-av-gron-teknik/.

Gross, R., Blyth, W., Heptonstall, P., 2010. Risks, revenues and investment in electricity generation: why policy needs to look beyond costs. Energy Econ. 32 (4), 796–804.

Haegermark, M., Kovacs, P., Dalenbäck, J.-O., 2017. Economic feasibility of solar photovoltaic rooftop systems in a complex setting: a Swedish case study. Energy 127, 18–29.

Hansen, A.R., Jacobsen, M.H., Gram-Hanssen, K., 2022. Characterizing the Danish energy prosumer: who buys solar PV systems and why do they buy them? Ecol. Econ. 193, 107333.

Heiskanen, E., Matschoss, K., 2017. Understanding the uneven diffusion of building-scale renewable energy systems: a review of household, local and country level factors in diverse European countries. Renew. Sust. Energ. Rev. 75, 580–591.

Hildenbrand, W., 1983. On the "Law of Demand". Econ. J. Econ. Soc. 997–1019.

Hoerl, A.E., Kennard, R.W., 2000. Ridge regression: biased estimation for nonorthogonal problems. Technometrics 80–86.

IEA, 2018. National Survey Report of PV Power Applications in Sweden, p. 2017.

IEA, 2022a. National Survey Report of PV Power Applications in Sweden, p. 2021. https://iea-pvps.org/wp-content/uploads/2022/10/National-Survey-Report-of-PV-Power-Applications-in-Sweden-2021.pdf.

IEA, 2022b. Solar PV. https://www.iea.org/reports/solar-pv.

IEA, 2022c. Trends in Photovoltaics Applications.

Jacksohn, A., Grösche, P., Rehdanz, K., Schröder, C., 2019. Drivers of renewable technology adoption in the household sector. Energy Econ. 81, 216–226.

Janke, T., Steinke, F., 2019. Forecasting the price distribution of continuous intraday electricity trading. Energies 12 (22), 4262.

Jenner, S., Groba, F., Indvik, J., 2013. Assessing the strength and effectiveness of renewable electricity feed-in tariffs in European Union countries. Energy Policy 52, 385–401.

Johnstone, N., Haščič, I., Popp, D., 2010. Renewable energy policies and technological innovation: evidence based on patent counts. Environ. Resour. Econ. 45, 133–155.

Juarez-Colunga, E., Dean, C., 2020. Negative binomial regression. In: Wiley StatsRef: Statistics Reference Online. https://doi.org/10.1002/9781118445112.stat08246.

Karneyeva, Y., Wüstenhagen, R., 2017. Solar feed-in tariffs in a post-grid parity world: the role of risk, investor diversity and business models. Energy Policy 106, 445–456.

Kastner, I., Stern, P.C., 2015. Examining the decision-making processes behind household energy investments: a review. Energy Res. Soc. Sci. 10, 72–89.

Kennedy, P., 2003. A Guide to Econometrics, 5th ed. In. MIT Press, Cambridge, MA.

Kesidou, S.L., Sorrell, S., 2018. Low-carbon innovation in non-domestic buildings: the importance of supply chain integration. Energy Res. Soc. Sci. 45, 195–213.

Konjunkturinstitutet, 2023. Barometerindikatorn och andra indikatorer, månad. http://statistik.konj.se/PxWeb/pxweb/sv/KonjBar/KonjBar_indikatorer/Indikatorm.px/.

Kopsakangas-Savolainen, M., Mattinen, M.K., Manninen, K., Nissinen, A., 2017. Hourly-based greenhouse gas emissions of electricity–cases demonstrating possibilities for households and companies to decrease their emissions. J. Clean. Prod. 153, 384–396.

Kumar, P., Gupta, S., Dagar, V., 2024. Sustainable energy development through non-residential rooftop solar photovoltaic adoption: empirical evidence from India. Sustainable Development 32 (1), 795–814.

Lekavičius, V., Bobinaitė, V., Galinis, A., Pažėraitė, A., 2020. Distributional impacts of investment subsidies for residential energy technologies. Renew. Sust. Energ. Rev. 130, 109961.

Li, J., Huang, J., 2020. The expansion of China's solar energy: challenges and policy options. Renew. Sust. Energ. Rev. 132, 110002.

Lindahl, J., Lingfors, D., Elmqvist, Å., Mignon, I., 2022. Economic analysis of the early market of centralized photovoltaic parks in Sweden. Renew. Energy 185, 1192–1208.

Loock, M., 2012. Going beyond best technology and lowest price: on renewable energy investors' preference for service-driven business models. Energy Policy 40, 21–27.

Lüthi, S., Wüstenhagen, R., 2012. The price of policy risk—empirical insights from choice experiments with European photovoltaic project developers. Energy Econ. 34 (4), 1001–1011.

Masini, A., Menichetti, E., 2012. Investment decisions in the renewable energy sector: an analysis of non-financial drivers. Technol. Forecast. Soc. Chang. 80 (3), 2013.

Menanteau, P., Finon, D., Lamy, M.-L., 2003. Prices versus quantities: choosing policies for promoting the development of renewable energy. Energy Policy 31 (8), 799–812.

Mignon, I., 2016. *Inducing large-scale diffusion of innovation - and integrated actor- and system-level approach* (Publication Number 1777) Linköping University. Linköping. http://liu.diva-portal.org/smash/record.jsf?pid=diva2%3A958063&dswid=-7721.

Mignon, I., Bergek, A., 2016a. Investments in renewable electricity production: the importance of policy revisited. Renew. Energy 88, 307–316.

Mignon, I., Bergek, A., 2016b. System-and actor-level challenges for diffusion of renewable electricity technologies: an international comparison. J. Clean. Prod. 128, 105–115.

Mitchell, C., Bauknecht, D., Connor, P.M., 2006. Effectiveness through risk reduction: a comparison of the renewable obligation in England and Wales and the feed-in system in Germany. Energy Policy 34 (3), 297–305.

Mundaca, L., Samahita, M., 2020. What drives home solar PV uptake? Subsidies, peer effects and visibility in Sweden. Energy Res. Soc. Sci. 60, 101319.

Niesten, E., Jolink, A., Chappin, M., 2018. Investments in the Dutch onshore wind energy industry: a review of investor profiles and the impact of renewable energy subsidies. Renew. Sust. Energ. Rev. 81, 2519–2525.

Özdemir, Ö., Hobbs, B.F., van Hout, M., Koutstaal, P.R., 2020. Capacity vs energy subsidies for promoting renewable investment: benefits and costs for the EU power market. Energy Policy 137, 111166.

Palm, A., 2015. An emerging innovation system for deployment of building-sited solar photovoltaics in Sweden. Environ. Innov. Soc. Trans. 15, 140–157.

Palm, A., 2017. Peer effects in residential solar photovoltaics adoption—a mixed methods study of Swedish users. Energy Res. Soc. Sci. 26, 1–10.

Palm, J., 2018. Household installation of solar panels–motives and barriers in a 10-year perspective. Energy Policy 113, 1–8.

Palm, A., Lantz, B., 2020. Information dissemination and residential solar PV adoption rates: the effect of an information campaign in Sweden. Energy Policy 142, 111540.

Palm, J., Tengvard, M., 2011. Motives for and barriers to household adoption of small-scale production of electricity: examples from Sweden. Sustain. Sci. Pract. Policy 7 (1), 6–15.

Pitelis, A., Vasilakos, N., Chalvatzis, K., 2020. Fostering innovation in renewable energy technologies: choice of policy instruments and effectiveness. Renew. Energy 151, 1163–1172.

Poier, S., 2021. Towards a psychology of solar energy: analyzing the effects of the Big Five personality traits on household solar energy adoption in Germany. Energy Res. Soc. Sci. 77, 102087.

Polzin, F., 2017. Mobilizing private finance for low-carbon innovation–a systematic review of barriers and solutions. Renew. Sust. Energ. Rev. 77, 525–535.

Polzin, F., Migendt, M., Täube, F.A., von Flotow, P., 2015. Public policy influence on renewable energy investments—a panel data study across OECD countries. Energy Policy 80, 98–111.

Polzin, F., Egli, F., Steffen, B., Schmidt, T.S., 2019. How do policies mobilize private finance for renewable energy?—a systematic review with an investor perspective. Appl. Energy 236, 1249–1268.

Poshnath, A., Rismanchi, B., Rajabifard, A., 2023. Adoption of renewable energy systems in common properties of multi-owned buildings: introduction of 'energy entitlement'. Energy Policy 174, 113465.

Provaty, S.S., Hasan, M.M., Luo, L., 2024. Organization capital and GHG emissions. Energy Econ. 107372.

PVInsight, 2022. Polysilicon Solar Price – PV Insights. http://pvinsights.com.

Reindl, K., Palm, J., 2021. Installing PV: barriers and enablers experienced by non-residential property owners. Renew. Sust. Energ. Rev. 141, 110829.

Resch, G., Ragwitz, M., Held, A., Faber, T., Haas, R., 2007. Feed-in tariffs and quotas for renewable energy in Europe. CESifo DICE Rep. 5 (4), 26–32.

Ringel, M., 2006. Fostering the use of renewable energies in the European Union: the race between feed-in tariffs and green certificates. Renew. Energy 31 (1), 1–17.

Rogers., 2003. Diffusion of Innovations, 5th ed. The Free Press.

Sadorsky, P., 2021. Wind energy for sustainable development: driving factors and future outlook. J. Clean. Prod. 289, 125779.

Sardianou, E., 2007. Estimating energy conservation patterns of Greek households. Energy Policy 35 (7), 3778–3791.

Sardianou, E., Genoudi, P., 2013. Which factors affect the willingness of consumers to adopt renewable energies? Renew. Energy 57, 1–4.

Selvakkumaran, S., Ahlgren, E.O., 2019. Determining the factors of household energy transitions: a multi-domain study. Technol. Soc. 57, 54–75.

Sheha, M., Mohammadi, K., Powell, K., 2021. Techno-economic analysis of the impact of dynamic electricity prices on solar penetration in a smart grid environment with distributed energy storage. Appl. Energy 282, 116168.

Skordoulis, M., Ntanos, S., Arabatzis, G., 2020. Socioeconomic evaluation of green energy investments: analyzing citizens' willingness to invest in photovoltaics in Greece. International Journal of Energy Sector Management 14 (5), 871–890.

Solangi, K., Islam, M., Saidur, R., Rahim, N., Fayaz, H., 2011. A review on global solar energy policy. Renew. Sust. Energ. Rev. 15 (4), 2149–2163.

Sommerfeldt, N., Lemoine, I., Madani, H., 2022. Hide and seek: the supply and demand of information for household solar photovoltaic investment. Energy Policy 161, 112726.

Spiller, E., Esparza, R., Mohlin, K., Tapia-Ahumada, K., Ünel, B., 2023. The role of electricity tariff design in distributed energy resource deployment. Energy Econ. 106500.

Statistics Sweden, 2023. Inflation in Sweden 1830–2022: Annual average change in percentage of consumer prices. https://www.scb.se/en/finding-statistics/statistics-by-subject-area/prices-and-consumption/consumer-price-index/consumer-price-index-cpi/pong/tables-and-graphs/consumer-price-index-cpi/inflation-in-sweden/.

Swedish Energy Agency, 2014. Underlag till revidering av förordning om solcellsstöd: En delrapportering med konkreta förslag till revidering av förordning (2009:689) om statligt stöd till solceller. https://www.energimyndigheten.se/globalassets/fornybart/solenergi/stod-till-solceller/underlag-till-revidering-av-forordning-solcellsstod-dnr_20147709.pdf.

Swedish Energy Agency, 2018. Förenklad administration av solcellsstödet: Redovisning av Energimyndighetens uppdrag att utreda hur administrationen av solcellsstödet kan förenklas. https://www.energimyndigheten.se/contentassets/e3f3b7a4796d43a895720fd1ecf6669f/er201819-forenklad-administration-av-solcellsstodet_slutversion.pdf.

The Swedish Consumer Energy Markets Bureau, 2023. Månadspriser på elbörsen mellan 1996 och 2022. The Swedish Consumer Energy Markets Bureau. https://www.energimarknadsbyran.se/el/dina-avtal-och-kostnader/elpriser-statistik/manadspriser-pa-elborsen/.

Tolliver, C., Keeley, A.R., Managi, S., 2020. Policy targets behind green bonds for renewable energy: do climate commitments matter? Technol. Forecast. Soc. Chang. 157, 120051.

United Nations, 2015. Paris agreement. https://www.un.org/en/climatechange/paris-agreement.

Ver Hoef, J.M., Boveng, P.L., 2007. Quasi-Poisson vs. negative binomial regression: how should we model overdispersed count data? Ecology 88 (11), 2766–2772.

Warneryd, M., Karltorp, K., 2020. The role of values for niche expansion: the case of solar photovoltaics on large buildings in Sweden. Energy Sustain. Soc. 10 (1), 1–13.

Wüstenhagen, R., Menichetti, E., 2012. Strategic choices for renewable energy investment: conceptual framework and opportunities for further research. Energy Policy 40, 1–10.

Yang, Z., Zhang, M., Liu, L., Zhou, D., 2022. Can renewable energy investment reduce carbon dioxide emissions? Evidence from scale and structure. Energy Econ. 112, 106181.

Yu, X., Ge, S., Zhou, D., Wang, Q., Chang, C.-T., Sang, X., 2022. Whether feed-in tariff can be effectively replaced or not? An integrated analysis of renewable portfolio standards and green certificate trading. Energy 245, 123241.

Zainali, S., Lindahl, J., Lindén, J., Stridh, B., 2023. LCOE distribution of PV for single-family dwellings in Sweden. Energy Rep. 10, 1951–1967.

Zhang, H., Zheng, Y., Ozturk, U.A., Li, S., 2016. The impact of subsidies on overcapacity: a comparison of wind and solar energy companies in China. Energy 94, 821–827.