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Announcing a Green New Deal: The Role of Policy Signals for Stimulating Entrepreneurship*

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Abstract

Policymakers increasingly recognize the potential of creating local industries and jobs around carbon-neutral technologies. In this paper we discuss whether policymakers can use information about green energy policies as a signal to stimulate the foundation of new companies. We explore empirically whether we can identify an impact of policy announcements on entry decision-making of new firms by using new data from the Swiss commercial registry. Our study reveals a significant relationship between information on future policies and firm entries indicating that credible policy announcements can spur new industry development. We then develop a theoretical model to substantiate the link between announcements of myopic governments and firm entry. We consider entrepreneurs investing in fixed costs the period before they produce based on the announced subsidy by the government but payed out in the subsequent period. We can show that governments can use announcements as important information for investment decisions and - as shown in the empirical analysis - foster new firm entries before the policy is in place. We finally discuss to which degree our results hold for a wider range of political institutions and conclude with the some implications for policymakers.

Keywords: Policy signal, Expectations, Credibility, Renewable Energy

JEL Classification: C25, E02, H23, H25, O33, Q48

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1 Introduction

The mitigation of climate change requires a massive conversion of the economy with far-reaching and unprecedented transitions in energy, land, and urban infrastructure as well as industrial systems (IPCC, 2018). Policies have proven crucial for past transformations and will be so for the current one. While climate policy was perceived as a means to fairly split the burden of mitigation until recently, policymakers increasingly recognize the potential of creating local industries and jobs around carbon-neutral technologies (Schmidt and Sewerin, 2017). Green energy production, transmission and distribution as well as the development of new services related to green energy use depict important business activities to cover the economy's need for energy. Thus, strategically embedding entrepreneurship into a policy framework seems to be crucial and has received great interest by policy makers (Cojoianu et al., 2020). In this paper we study the interplay between the planning and set up of green policy and entrepreneurship.

While scholars have empirically analysed a broad range of policy instruments expected to foster entrepreneurship (see e.g. Block et al., 2017, Darnihamedani et al., 2018, Al-Saleh and Mahroum, 2015, Branstetter et al., 2014) the literature is sparse with regards to industry built-up in response to future policy intentions. In light of the long-term horizon of climate policy-making and respective targets, the role of policy information as signals for an entrepreneurial decision and new firm foundations seems to be of paramount importance. Scholars underline the role of long-term policy targets in order to align firms' innovation activities (Schmidt, Schneider, et al., 2012) and investments (Stern, 2022). In the area of monetary policy, a huge body of literature related to announcement effects and time-consistency issues suggests that policymakers successfully use information to align market expectations (e.g. Romer and Romer, 2000). Thus, information on policy measures or future policy frameworks is used as a signal to market actors which allows them to align their expectations on future prices. Yet, the role of policy as information for new business foundation in the context of the energy transition has not been analyzed, despite that such information seems to be core for the formation of entrepreneur's expectations about the evolution of the future business.

Existing theoretical literature focuses on the implementation of taxes and subsidies aimed at an acceleration of green innovations to speed up the decarbonization of the growth process at large. Conceptually, these papers build on seminal contributions by Acemoglu (1998), Acemoglu and Zilibotti (2001) and Acemoglu, Aghion, et al. (2012) and emphasise the relevance of relative market sizes for the development of green versus polluting innovations. They are thus history-dependent. Complementing this strand of literature, more recent papers sought to stress the impact of expectations in the context of the energy transition (Bretschger and Schaefer, 2017, Schaefer and Stünzi, 2019). These contributions, however, do not address the gradual entry of firms into a sector in response to signals of policy makers related to their future policy intentions.

In this paper we propose that early information on future climate policies, similar to announcements on inflation targets in monetary policymaking, can serve as an important signal to entrepreneurs and thereby influence new entries of firms. We combine an empirical analysis with a theoretical model to shed light onto the role of announcements about future policy instruments. In the first part of the paper we empirically analyze signaling effects of credible policy announcements and the evolution of a firm landscape in the context of the Swiss energy transition. For the analysis we use a new dataset that we build from the online archive of the Swiss commercial registry from 2002 until 2018. We identify key decisions in the Swiss parliament for supporting green energy and test whether the number of firm registration in the green energy sector changes following such major decisions. The central identifying assumption is that we would not observe a similar number of firm entries, conditional on controls, in a comparable business sector after an announced green policy while we do see a change in the green energy one. Our study reveals a highly significant relationship between information on future policies and firm entries. In particular, the announced introduction of a feed-in tariff two years before its enactment transpires to have been an important signal for entrepreneurs, resulting in early market entries and industry built up. Swiss policymakers are considered very trustworthy (OECD, 2017) which is an important prerequisite for policy signalling (see the literature in monetary policy). In the second part of the paper we seek to embed the empirical findings within a theoretical framework and discuss the role of announcements beyond a high certainty.

We develop a stylised model comprising entrepreneurs that invest in their technology before they produce given their expectations about the government's policy in terms of a green subsidy. Conceptually, we build on a framework of appropriate technologies (Acemoglu and Zilibotti, 2001) in the sense that two energy types can be used for the production of a certain intermediate. As energy types may be more or less productive for the production of a certain intermediate, set-up costs and relative profitabilities of both energy types trigger the use of these at the extensive margin. This is precisely where the policymaker becomes relevant by announcing a subsidy for green energy producers for the subsequent period based on which agents decide in the current period to enter the market by investing in fixed costs. As firms become active in the subsequent period the natural problem of time consistency emerges in terms of the government's announcement and its actual policy in the subsequent period. We are interested in the potential clash between short sighted governments who might be intrinsically unable to commit credibly to an announced policy and entrepreneurs taking their investment decisions based on these announcements.[2] The discussion about the relevance of announcements thus involves the dimensions of credibility and time-consistency. While the short time horizon of governments in office constitutes a problem in itself, the incentive to deviate in the future from an earlier announcement constitutes a major source of uncertainty for entrepreneurs. Conceptually, this uncertainty is rooted in agents' inability to observe the true preferences of the policymaker, in the sense that it might mimic certain policy objectives and reveal its true identity only in the future. All these channels are very realistic in the sense that the limited planning horizon stems from the political election process while hiding its true preferences might be in the interest of a government when decisions are taken sequentially.

The contribution of this paper is two-fold. First, we empirically identify the impact of credible policy signals on green energy entrepreneurship. Second, we propose a theoretical model to rationalise the importance of policy announcements for entrepreneurial planning. For policymakers our results support the idea that clear directions and respective policies contribute to achieving these very same goals, but also stress the necessity of credibility. The reminder of the paper is structured as follows. In section 2 we describe our data, method and the results of the empirical analysis. In section 3 we introduce the model and analyze the credibility of announcements by weak and strong governments. In section 4, we provide a discussion of our findings and finally, section 5 concludes.

2 Empirical Analysis

In the following section we analyze the empirical relationship between credible signaling and respective market entries in the renewable energy sector. Our analysis adds to the existing literature in two areas: first, on entry decision and industry formation and second, on the

[2] Earlier contributions in monetary economics dealing with the inflation bias argument reason convincingly that policymakers may be unable to commit credibly to their announcements as decisions are taken sequentially. In other words they may deviate from their previous announcements in order to increase their utility by surprising the public with an unexpected inflation rate (Barro and Gordon, 1983).

importance of green policy measures.

Existing papers use cross-country analyses to study the effect of entry costs (e.g. Klapper et al., 2006, Branstetter et al., 2014), labour regulations (Aghion et al., 2007), entry costs and corporate income taxation (Da Rin et al., 2011). With regards to green entrepreneurship, Cojoianu et al. (2020) analyze how different types of environmental policies and new regional environmental knowledge affect new venture creation across 24 OECD countries between 2001 and 2013. The authors highlight the importance of existing infrastructure and regional research institutes and that more stringent environmental policy has negatively impacted new entries in the fossil fuel sector. Linked to new business foundation there is only few literature with regards to the formation of expectations on future policy frameworks. One strand of entrepreneurship literature puts forward that positive expectations are a key characteristic of entrepreneurs. For example, with data from the Global Entrepreneurship Monitor (GEM) Bager and Schøtt (2014) show that starters of new businesses frequently have high expectations for growth compared to managers of young and mature businesses. High levels of confidence foster entry decisions in game experiments on market entry (Bolger et al., 2008) and induce high growth expectations (Szerb and Vörös, 2019). Frese and Gielnik (2014) discuss meta-analytic findings of personality dimensions associated with entrepreneurship and Hermans et al. (2015) center on their relationship with entrepreneurial ambitions. Cooper et al. (1988) show that entrepreneurs display a remarkable degree of optimism, also interpreted as feelings of entrepreneurial euphoria when first becoming a business owner. However, and aside the individual traits for optimism, the formation of expectations is not fully understood.

With regards to green policy measures there has evolved a broad range of literature, in particular analysing types of measures and related effectiveness of policies to stimulate the expansion of green energy sources (for a review see for example Kihlström and Elbe (2021) and Gao (2021)). To accelerate the transition, governments have played a crucial role in creating conditions that encourage new and existing firms to invest in technologies that increase production of and demand for renewable energy (Kihlström and Elbe, 2021). Yet, there is limited evidence related to the influence of environmental policy on entrepreneurship (see e.g. Cojoianu et al. (2020)). The authors find that feed-in tariff policies significantly impact the attraction of investment for renewable energy generation and closely related technologies in the value chain of electricity generation (including grid, biofuels, materials) and service-oriented start-ups in the green sector such as consultancy. Thus, feed-in-tariffs and emission standards catalyze increased investment in green start-ups since they promise a stable flow of revenues (Cojoianu et al., 2020). On the other hand, Gao (2021) finds that favorable regulatory policies are associated with an increased number of startups and subsidiaries in the solar energy sector in the US while the author doesn't find a clear positive relationship with financial incentive policies. Finally, Georgallis et al. (2019) propose that the introduction of feed-in tariffs is more likely in countries with greater numbers of solar PV producers. While a growing industry and allies from social movement organisations may indeed push for the implementation of supporting policies, we propose that industry built-up (also) happens in light of expected policy changes. Green energy policy measures that are going to increase demand for green energy and services positively influence the success expectations of entrepreneurs. Complementing the existing literature our study explores not only policies' enactment, but already when they are credibly announced.

Taking the case of Switzerland we can indeed study whether credible announcements on future environmental policies trigger a higher entry rate of green energy entrepreneurs. Switzerland is an interesting country for multiple reasons. First, it is a country where policymakers are trusted most compared to all other OECD countries (OECD, 2017). Second, the Swiss political system created contestability that led to political stability throughout history (Weder and Weder, 2012). Building expectations about future policies and a related business opportunities is less likely to be tarnished by sudden mind shifts or governmental changes that would roll back an announced policy. Third, Switzerland has set an ambitious target for increasing the use of renewable energies. As of now, the main sources of energy in Switzerland are imported petroleum and other fuels (50%) and electricity (25%) (BFE, 2017). The latter is mainly generated by hydropower (59.9%), nuclear power (33.5%) and conventional thermal power plants (2.3%, non-renewable). Other renewable energy sources are still small[3] but Switzerland has set itself the goal of raising the share of renewables by at least 50% between 2010 and 2020 combined with a nuclear phase-out and a reduction of energy use by 2035 (BFE, 2017). Yet, the policy-based promotion of renewable energy production and consumption has started much earlier. In 1998 the energy act provides, among other things, for the increased use of renewable energies followed by multiple policy measures aiming to increase the share of new renewables. In particular, in 2009 a feed-in tariff was introduced, followed by transparency regulations and subsidies for upfront investments for small-scale renewable power projects. Scholars have dis-

[3]E.g. wood (16.4%), waste incineration (11%), geothermal power (6.2%), solar power (2.8%), biogas (2%), wind power (0.2%) and biofuels (0.1%)

cussed the history and design of the Swiss energy policy framework (e.g. Haelg et al., 2022), and how political regulations at the cantonal level interact with national policies (Stadelmann et al., 2019). Yet, none of this important work is able to explore the impact of these policies on industry development at the firm level.

2.1 Data

Our empirical analysis is based on a novel dataset created from the Swiss business registry between 2002 and 2018 and data on Swiss energy policy from the database of parliamentary proceedings in Switzerland.

Firm registries The use of commercial registry data offers a census-like database which allows the identification of all new businesses (see also Weinhardt and Stamm (2019) who propose the use of commercial registry data for Germany). In Switzerland, the *Eidgenössisches Amt für das Handelsregister* (EHRA) is responsible for the maintenance of the commercial registry, which publishes daily the *Schweizerisches Handelsamtsblatt* (SHAB). These documents are public and contain information on the legal nature of firms and the associated requirements, in particular the creation and cessation of a firm, its purpose, location and owners. While each canton is responsible for its registry's publication, the federal government had been aggregating the information at the federal level. Yearly publications are available at the national level stored in an online portal since 2002.

In order to identify the firms in the renewable energy sector we use a keyword search to scan the description of the purpose. We use the keyword stems "solar" and "renewable" in the three national languages (German, French and Italian). After removing duplicates we have 2676 newly registered firms between January 2002 and August 2018. Random checks of the dataset did not reveal any organisations from another sector that were wrongly identified as a green energy firm. In appendix A we describe the sensitivity of the keyword search and respective robustness.

For making causal analyses we need to compare the changes in the solar industry to another sector that is similarly affected by the general policy environment but not by targeted green energy policy. Comparing the Swiss sector to another country is difficult for two reasons. First, such granular data on green energy firm entries is not available. Second, there are substantial country-differences with regards to entry conditions and (green) policies. Instead, and based on extensive research and expert inputs we identify Swiss firms distributing and offering services on telecommunication (phones) as a control group. The telecommunication sector was growing substantially in the same time period (see e.g. BFS (2021a), number of phone contracts doubled between 2002 and 2018), is highly technology-based, depends on similar import restrictions/liberations from Asia and is identifiable as a separate business activity sector in the business registry. For the control group we use a similar approach but with the word stem "phone" (again in all three languages). The control group contains 3094 newly registered firms.

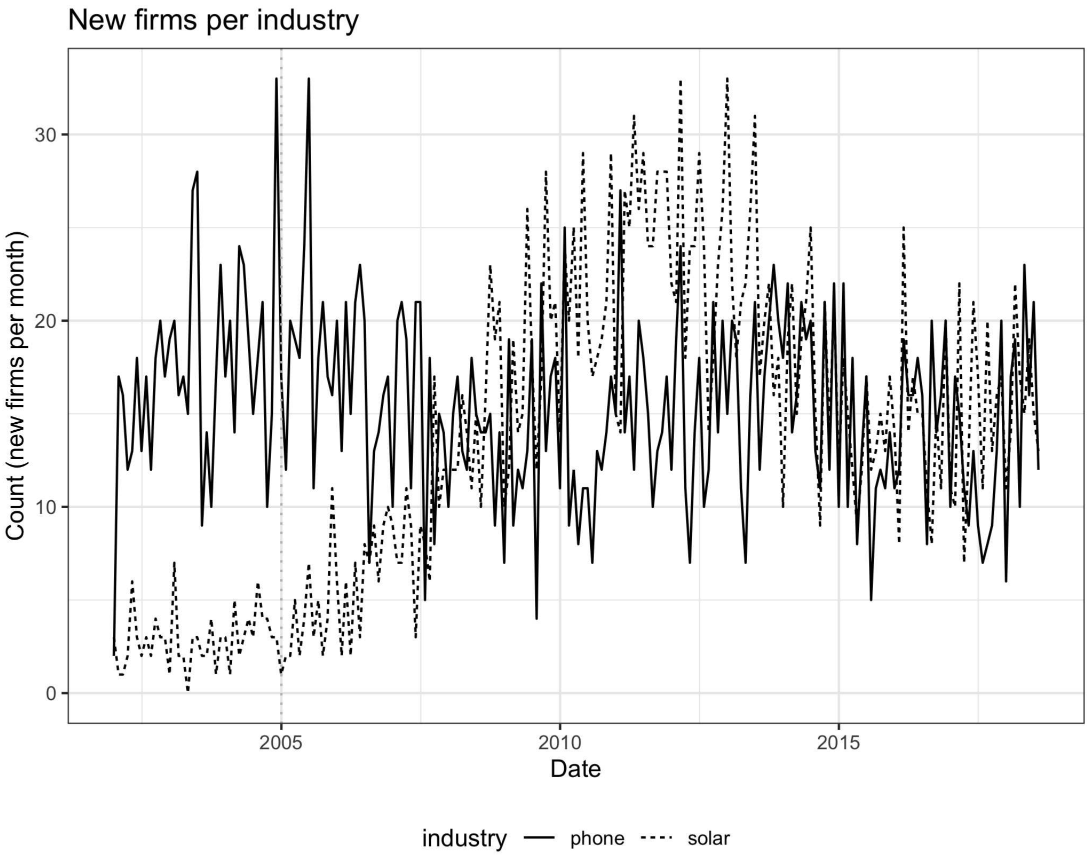

Figure 1: New firms in the green energy sector in Switzerland compared to new firms in the phone industry. Dotted line marks the begin of January 2005, data from 2002-2004 is taken as reference level for the empirical analysis.

Figure 1 shows the number of firms entries over the entire time span. There is seasonal variability for both industries. For the green energy industry there was a light increase from 2006 onwards and a more substantial increase from 2007 until 2012, a decrease between 2013 and 2015 and a stabilization since 2015. In comparison, initially there was a higher average number of firms in the phone sector but new firm entries remained on a relatively stable level throughout the whole time period.

For the analysis we take the years 2002-2004 as a reference level. We aggregate the firm entries per month ('Count') and divide it by the average number of firm entries per month of the years 2002-2004 ('CountAv'). Overall, this yields 400 observations (average number of firms per month for 200 months per industry).

Policy signals For the signal variables we focus on the three most important policy decisions for promoting green energy deployment and consumption in Switzerland based on the database of parliamentary proceedings in Switzerland (Curia Vista, 2022). We separately determine announcements (date of decision in the parliament which is made public the same day) and implementation date (see table 4 in appendix A) and reviewed them with representatives from the Swiss Federal Office for Energy. The policies aim to increase the share of renewable energy consumption by increasing the revenues for selling the electricity to the local energy providers with a feed-in subsidy ('KEV'), reducing the upfront investment cost ('EIV') and increasing overall transparency towards the customers about the energy mix ('New transparency guidelines'). The timespan between the announcement and implementation dates differs substantially between the policies. The longest timespan between announcement and implementation is the KEV (decided in march 2007, enacted on January 1st 2009). Since this was the first policy measure to actively incentivize the installation of solar panels we also consider it to be the most important signal. We create a factor variable for each policy differing between the pre-announcement, the announcement/pre-enactment and the post-enactment period.

Control variables Finally, we include a variety of control variables. The data shows that there is considerable variations in firm entries, thus, more new entries in spring and in the end of the year. To control for seasonal variation we create monthly dummies.

To account for the general economic environment we include variables for entrepreneurial activity (number of all new firms registered per year, with data from SHAB (2021)), national income (GDP) and the unemployment rate. For GDP and annual unemployment rates we use data from the Federal Office for Statistics (BFS, 2021b, 2021).

The development of green energy use in Switzerland has been strongly monitored and debated at the national policy level but, at the same time, also been affected by trends on the global level. Similar to other countries, the solar industry development is marked by a strong increase in competition for the production of solar modules, mainly in China, which is considered one of the main reasons for the collapse of solar module producing industry in Europe. The development of green energy use and, in particular, solar energy is marked by a steep decrease in the price of solar modules (see e.g. IRENA, 2019). Lower prices for the modules, on the other hand, are beneficial to service providers, such as installers of solar systems. To account for that we control for the primary costs of solar modules (available per year) with data from IRENA (2019). Furthermore, the development of the Swiss industry is highly driven by exports (EBP and Rütter, 2012). We, thus, include data on the deployment of renewable energy in Germany as a proxy for increasing demand outside Switzerland. We use annual data from (AGEE-Stat, 2021) on the gross deployment of renewable energy in Germany from 2002-2018. Table 1 shows the summary statistics of the dataset.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Count	400	14.425	6.980	0	10	19	33
CountAv	400	2.766	2.769	0.000	0.814	4.587	11.423
GDP	17	609,697.900	72,299.200	483,440.000	556,438.800	672,818.200	719,271.600
Unemployment	17	133,447.100	16,875.680	100,504.100	122,892.000	146,088.900	153,091.300
Firm.Entries	17	36,939.320	4,251.130	28,112	34,209	40,840	43,420
Solar.Prices	17	0.473	0.335	0.090	0.170	0.900	0.970
DE_Renewables	17	119.518	55.886	45.500	72.300	162.500	217.900

Table 1: Summary Statistics

2.2 Model

Our empirical specification estimates the effects of announced and implemented green energy policies on the number of firm entries by exploiting the fact that the policies only had an impact on the green energy sector but not on any other sector. We differentiate the effects of the announcement and enactment period by defining factor variables that are equal to 0 before the announcement, 1 after the announcement and 2 after the implementation dates. We interact these variables with an indicator whether the firm belongs to the green energy or the phone sector. Using these variables we estimate the following DiD model for outcome $y_{s,t}$ of sector s in month t:

$$y_{s,t} = \beta_0 + \sum \beta_{pol_{i,t}} \cdot x_{pol_{i,t}} + \sum \beta_{did_{pol_{i,t}}} (x_{pol_{i,t}} \cdot sector) + \eta_s + \alpha_t + \gamma Controls + \varepsilon_{i,t} \quad (1)$$

where $y_{s,t}$ is the number of new firm entries per month for sector s (green energy or phone) divided by the average number of monthly entries from 2002-2004. The first sum includes the coefficients for each green energy policy measure. The second sum includes the interaction between the sector and these policies. η_s controls for sector-specific effects, α_t for seasonal variation (monthly) and γ for the additional control variables, i.e. controls for the economic environment (GDP, unemployment and overall new firm entries) and controls for the global development of the solar industry (prices for PV modules and renewable energy deployment in Germany), as described above. The central identifying assumption of our approach is that we would observe a similar number of firm entries, conditional on controls, in the phone sector after an announced green policy, while we do see a change in the green energy one.

2.3 Results

Our empirical strategy is based on the idea that the (credible) announcement of green energy policies already triggered a higher entry rate of new firms, thus, before the policy was enacted. Figure 2 provides descriptive evidence that supports this idea. It illustrates the different time periods when policies were announced and set in place. The number of firm entries per month started to increase after 2005 and the increase became more steep after the decision to introduce the KEV in 2007. The level of firm entries remained higher after the decision on the KEV introduction.

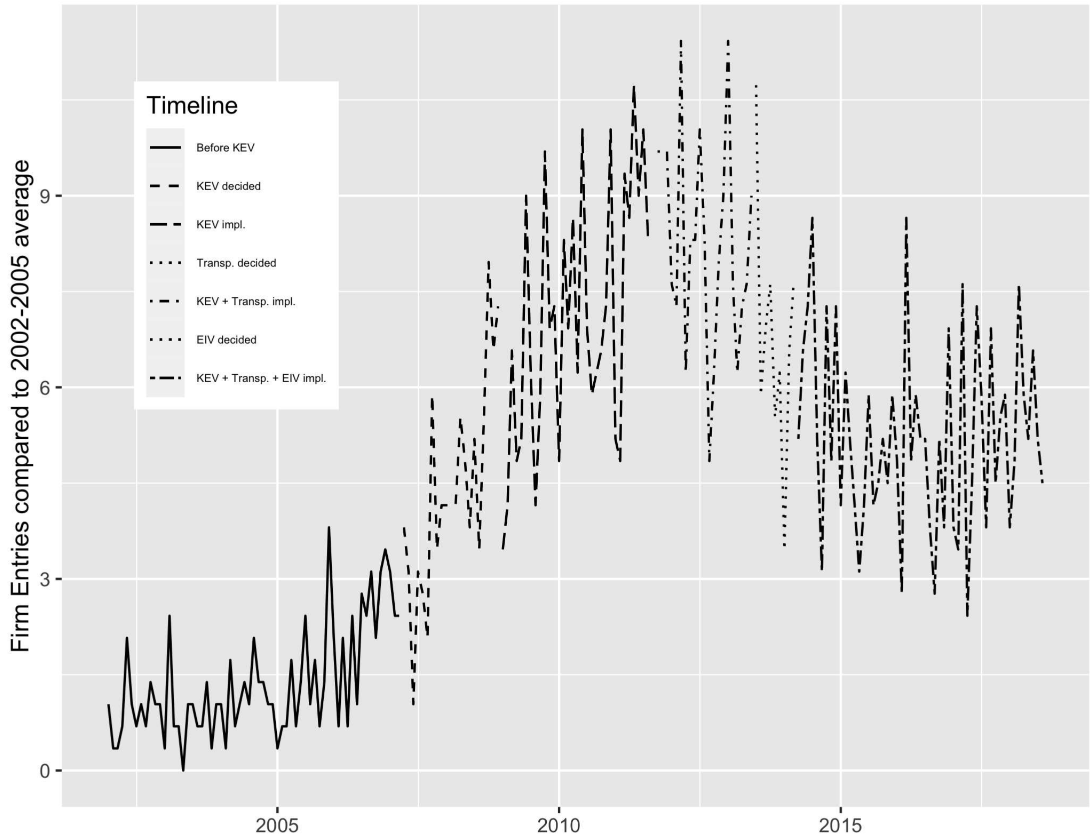

Figure 2: Number of firm entries related to green energy, separated by the different policy periods.

Main Results In table 2 one can see the regression coefficients. Overall, the coefficient for the solar industry is positive, since there are more new firms registered in the solar energy sector levelised to the 2002-2004 average. Columns 1-3 show the results without the interaction coefficient, columns 4-6 with the interaction. Columns 2 and 5 include the temporal control variable, columns 4 and 6 also the controls for the economic environment. The interaction coefficient is highly significant for the KEV policy (positive) as well as for the EIV policy (negative). Thus, both, during the announcement period as well as after the implementation of these two policies, the number of firm entries in the solar industry significantly increased or decreased, respectively. The transparency policy coefficient is only significant for the implementation but not for the announcement. In sum, we identify the implementation of the three policies as significant for the average number of firm entries in the green energy sector and, in addition, identify the dates of decision and announcements of these policies as significant for the feed-in tariff (KEV) and the investment cost reduction (EIV), too.

	Dependent variable:					
	CountAv					
	(1)	(2)	(3)	(4)	(5)	(6)
industrysolar	3.732***	3.732***	3.732***	0.362	0.362*	0.362*
	(0.167)	(0.165)	(0.164)	(0.192)	(0.184)	(0.177)
kev1	1.412***	1.388***	−0.423	−0.186	−0.210	−2.022***
	(0.297)	(0.295)	(0.634)	(0.272)	(0.260)	(0.424)
kev2	2.772***	2.780***	0.606	−0.190	−0.181	−2.356***
	(0.256)	(0.254)	(1.054)	(0.234)	(0.224)	(0.659)
eiv1	−0.752	−0.719	−0.813	0.195	0.227	0.134
	(0.453)	(0.451)	(0.464)	(0.415)	(0.397)	(0.391)
eiv2	−1.538***	−1.527***	−1.440**	−0.041	−0.029	0.057
	(0.305)	(0.303)	(0.511)	(0.279)	(0.267)	(0.360)
trans1	0.480	0.793	0.429	−0.240	0.073	−0.292
	(1.197)	(1.221)	(1.233)	(1.096)	(1.063)	(1.036)
trans2	0.608	0.578	0.279	0.048	0.018	−0.281
	(0.331)	(0.329)	(0.461)	(0.303)	(0.290)	(0.343)
industrysolar:kev1				3.197***	3.197***	3.197***
				(0.385)	(0.367)	(0.355)
industrysolar:kev2				5.924***	5.924***	5.924***
				(0.331)	(0.316)	(0.306)
industrysolar:eiv1				−1.892**	−1.892***	−1.892***
				(0.587)	(0.560)	(0.541)
industrysolar:eiv2				−2.995***	−2.995***	−2.995***
				(0.395)	(0.377)	(0.364)
industrysolar:trans1				1.441	1.441	1.441
				(1.550)	(1.481)	(1.430)
industrysolar:trans2				1.120**	1.120**	1.120**
				(0.429)	(0.409)	(0.395)
Seasonal Controls		✓	✓		✓	✓
Economic Controls			✓			✓
Constant	−0.673***	−1.157***	−6.421	1.012***	0.528*	−4.736*
	(0.170)	(0.317)	(3.888)	(0.136)	(0.212)	(2.367)
Observations	400	400	400	400	400	400
R^2	0.644	0.661	0.671	0.853	0.870	0.880
Adjusted R^2	0.637	0.645	0.651	0.848	0.861	0.871
Residual Std. Error	1.667 (df = 392)	1.651 (df = 381)	1.636 (df = 376)	1.079 (df = 386)	1.031 (df = 375)	0.995 (df = 370)
F Statistic	101.238*** (df = 7; 392)	41.199*** (df = 18; 381)	33.344*** (df = 23; 376)	172.283*** (df = 13; 386)	104.329*** (df = 24; 375)	93.700*** (df = 29; 370)
Note:						*p<0.05; **p<0.01; ***p<0.001

Table 2: DiD regression for solar and phone industry. Columns 2 and 5 include controls for seasonal variation (monthly dummies), columns 3 and 6 also for overall business environment, see table 1

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Robustness checks In addition to the main analysis we perform a couple of alternative specifications that can be found in the appendix (see A). In particular, we look at one additional, national policy decision and two international events that could increase entrepreneurs' expectations about a favorable business environment. On the national level we analyze the impact of a popular vote about the new energy strategy in Switzerland which was a package of policies ('ES2050'). The inclusion did not alter the main results.

On the international level we identified two events that could have affected expectations: the nuclear disaster in Fukushima in 2011 that was followed by exit decisions from nuclear power production in multiple countries, including Switzerland, and the Paris Agreement on mitigating climate change in December 2015. Accounting for these two events did not alter the significance or direction of our coefficients. However, the coefficient for the Fukushima disaster is positive and significant, indicating that the disaster may have also triggered expectations about subsequent business based on renewable energy production and consumption rather than use of nuclear power.

2.4 Preliminary Discussion

Our empirical analysissuggests that the moment of the policy decision has served as a strong, credible signal for entrepreneurs to enter the market of green energy products and services. Haelg et al. (2022) summarise that industry development and job creation were important arguments in favor of the the feed-in tariff policy in the parliamentary debate preceeding the KEV decision. The highly significant, positive coefficient for both, the post-announcement and the post-enactment period support the interpretation that this was successful already before the policy was in place. The aim of our analysis is not to explain the impact of any of these arguments for policy choices but only show, that already the moment of the decision and (public) signaling has influenced the built-up of the industry.

What reasons could explain the negative coefficient of the EIV policy? A combination of unexpected high numbers of registrations on the one hand and a large underfunding on the other hand let to a long waiting list of projects to be approved (BFE, 2017; Haelg et al., 2022). In response to this growing challenge the EIV was implemented. While it was argued that a one-time support in the primary investment costs was still more beneficial than long waiting periods and uncertainty about whether and when households will receive renumeration via the KEV, the EIV is a much smaller subsidy and only available for small-scale plants. The significant (negative) coefficient for the EIV policy announcement could indicate both, lower expectations because of a less supportive policy environment or uncertainty about the actual implementation of the EIV policy given the experiences with the long waiting list of the KEV policy. In the first case the policy and its announcement had a negative effect on the number of firm entries. In the latter case the EIV and its announcement were not able to reverse an already existing negative trend and it was not credible enough a supportive policy. The Swiss Federal Office for Energy acknowledged that the long waiting list and uncertainties regarding the KEV once implemented, led to a certain distrust and "wait and see" attitude with regards to new policies. This indicates that, similar to monetary policy theory, trust in governments and policies can quickly vanish.

Finally, the non-significance of the transparency coefficient (the announcement) may be explained with two reasons: first, the time period between announcement and implementation was very short (2 months, compared to almost 2 years for the KEV). Second, more transparency may not have an immediate effect on green energy supply and demand compared to financial support.

While our empirical results are very robust to alternative specifications, our study has certain limitations. First, note that we do not identify the underlying reason for the increase in market entries after the KEV decision. We are not able to determine whether entrepreneurs have more optimistic expectations about the evolution of the future policy framework and therefore the respective business case or whether the policies facilitated access to venture capital (as suggested by Cojoianu et al., 2020) and thereby new firm foundation. In addition, the shape of the new firms entry curve resembles data on the solar energy industry development and collapse (see e.g. RTS, 2017) which is generally explained with the increasing competition mainly from China. Since we look at new entries only, a slower entry rate may also reflect perceived strong competition from abroad or early market saturation. This does, however, not diminish the interesting result we find with regards to the effect of policy signals: for a policy which triggers higher (lower) entry rates of new firms we can detect this effect already before the enactment of the policy, namely, after its announcement.

Second, our empirical estimation is bound to new registrations only. Note that we do not observe whether and how long the new firms stay in the market and how much they actually contribute to the energy transition. Guzman and Stern (2020) and Branstetter et al. (2014) emphasize the necessity to analyze not only the quantity, but also the quality of entrepreneurship. Yet, the focus of this paper is on the impact of policy signaling: we observe that after a supportive policy signal to the particular industry the number of firm entries increases. How successful the policy was and is to create a sustainable industry built-up is not part of this analysis. In addition, we focus on national policies and respective information and neglect any additional support on a regional or communal level. While in Switzerland energy policy was explicitly assigned to the federal policy level following the oil crisis in 1973 (BFE, 2019) it is possible that additional cantonal or communal policies further stimulated or hindered the impact of the national policies (see e.g. Stadelmann et al., 2019). Finally, there is also the possibility to enter a new industry as an existing firm (Klapper et al., 2006), for example by expanding or changing the business model. Here we do not address the role of feedback effects between policy, the existing industry and industry built-up. Georgallis et al. (2019) suggest that a growing industry itself push for more supportive policies and Meckling et al. (2015) emphasize the positive feedback of industry built-up that increase the pressure to keep and tighten policies in favor of these industries. Specifically for the Swiss energy system Haelg et al. (2022) find that the local industry was decisive for the definition of the specificities of the feed-in tariff which would benefit their home industry. The analysis of firm mutations and exits, the long-term impact of specific policies and entrepreneurial quality, the role of local legislation and the interplay between industry built-up and lobbying for policies goes beyond the scope of the empirical analysis but offer interesting pistes for future research.

In sum, our empirical analysis emphasizes the necessity to understand the connection between policy announcements and economic activity. Georgallis et al. (2019) argue that a higher number of producers and business in the green energy sector lead to a more supportive policy environment. Our analysis, explicitly taking into account the time period before the policies are enacted, suggests that such industry build-up could also be driven by expectations following credible policy announcements. We find that for Switzerland, where the government is considered to be very credible, the number of firm entries significantly increased already after the decision and public announcement of the feed-in tariff (KEV). While the literature agrees that certain policies can successfully trigger business development and market entries, our results show that this is already the case for the time period between the announcement and the implementation. In the next section we propose a theoretical framework to embed our empirical findings.

3 Theory

Our empirical findings suggest that entrepreneurs perceive policymakers' announcements as credible and enter a market prospectively. Apparently, the credibility of the Swiss government is very high. In this sense our empirical study serves as a controlled experiment to establish a benchmark case for our theoretical analysis. In this section we, therefore, aim to assess the potential of policy signals beyond Switzerland by analysing the underlying mechanisms theoretically. In particular, we first explore the impact of information regarding a future subsidy on their incentives to invest today and, second, explore the incentives for a government to credibly commit to an announced policy. Finally, we assess under what conditions deviations from an announcement become more or less likely.

We consider a small open economy populated by a measure L of households employed either in a polluting sector p or a clean sector c. Time proceeds in discrete steps, $t = 0, 1, 2, ..., \infty$. The economy assembles final output (Y) with intermediates (y) produced with either clean or polluting energy services and equipment (physical capital). In order to address the features of the energy transition in relation to the production side appropriately, we introduce a framework that allows for a contemporaneous activity of clean and polluting firms with different degrees of complications to adopt clean energies at a given state of technology. We therefore allow for firm heterogeneities in the intermediate sector in terms of the appropriateness of energy services for the production of a certain type of intermediate. Conceptually, this feature is captured by sector specific productivities of energy services in combination with installed capital equipment. These comparative advantages can be altered by the policymaker through subsidies affecting the degree to which the economy is able to produce with clean energy services at a given state of technology. The introduction of firm heterogeneities allows us to look from a macroeconomic perspective at the credibility problems related to government announcements. Market entry of energy suppliers is endogenous and in terms of the green energy supply supported by a subsidy of fixed costs. Entrepreneurs invest in fixed costs the period before their firms become active.

Resembling credibility of political decision-making, as was the case for the Swiss KEV introduction, we seek to analyze the impact of a subsidy announcement on investment decisions of entrepreneurs. In the first period in office the policymaker announces a subsidy for the subsequent period based on which entrepreneurs decide to enter the market becoming active in the next period. We extend this analysis and distinguish two types of governments with different degrees of environmental preferences being unobservable for the audience. As such we can analyze what happens if announcements are made which may not be hold in the next period. Conceptually we are interested in the effects of politically motivated short-sighted governments with a limited planning horizon. We then analyze if a government with weaker environmental preferences might have an incentive to mimic a government with strong environmental preferences by announcing a higher subsidy to green energy suppliers but deviating to a lower subsidy in the subsequent period. On the other hand, both types of governments might have an incentive to reveal their identities right from the beginning by making appropriate announcements. If the latter is the case, policy announcements are perceived as credible and can help fostering a new market. In figure 4 we have illustrated the timeline of events in these regimes graphically.

3.1 Production

Final output In period t, final output Y_t is composed of a continuum of intermediates $y_t(i)$

$$Y_t = \exp\Big[\int_0^1 \ln y_t(i)\; di\Big], \tag{2}$$

such that $i \in [0, 1]$. Moreover, Y is defined as the numeraire good, i.e. $p_Y = 1$.

Intermediate sector Intermediates $y(i)$ can be produced with a polluting or a clean technology denoted by indices c, p, respectively

$$\begin{aligned} y_t(i) &= \tilde{a}_{p,t}(i)^{1-\alpha} \cdot \int_0^{N_{p,t}} [(1-i) \cdot x_{p,t}(i, \omega_p)]^\alpha d\omega_p \\ &+ \tilde{a}_{c,t}(i)^{1-\alpha} \cdot \int_0^{N_{c,t}} [(i) \cdot x_{c,t}(i, \omega_c)]^\alpha d\omega_c, \end{aligned} \tag{3}$$

where $\tilde{a}_j, j = c, p$ denotes capital equipment in sector i, N_j the range of available energy services complementary to the respective type of equipment, and x_j the quantity of a certain type of energy service $\omega_j \in [0, N_{j,t}]$ employed in sector i. The factors $(1-i)$ and (i) associated to x_p and x_c respectively indicate sector-specific productivities, in the sense that polluting energy which can only be combined with machines of type $\tilde{a}_p$ has high productivities in sectors indicated by a low $i \in [0, 1]$ while clean energy exhibits high productivities in sectors with a high i.[4] The

[4]We argue that at a given state of technology in the short/medium run, i.e. over the office term of a government, productivities and thus the compatibility of certain energy services is given in the sense that very energy intensive sectors like concrete or aluminium production are unable to rely completely on green energies.

range of available energy services is determined by market entries into the respective sector and subject to fixed costs F_j. Hence, the supply of quantity x_j of type ω_j occurs under monopolistic competition.

Energy services Production of polluting energy services uses a fossil natural resource e and labour l_p while green energy service producers make use of equipment $\tilde{a}_{c,x}$ and hire labour l_c

$$x(\omega_p) = [l_p(\omega_p)]^{\beta} \cdot [e(\omega_p)]^{1-\beta} \tag{4}$$

$$x(\omega_c) = [l_c(\omega_c)]^{\beta} \cdot [\tilde{a}_{c,x}(\omega_c)]^{1-\beta}, \qquad \beta \in (0,1). \tag{5}$$

3.2 The households' and the government's problem

The objective of the government is to maximize aggregate social welfare while it may be unable to commit to its previous announcement in terms of a subsidy to clean energy producers. As our research question is related to credibility aspects of policy announcements, we keep the households' utility maximisation problem deliberately simple. Households i work either in the clean or the polluting sector and maximise

$$U_{i,t} = \sum_{t=0}^{\infty} \rho^t \Big\{ c_{i,t} - \mu P_t^2 \Big\}, \qquad i = c, p, \tag{6}$$

where $\rho \in (0,1)$ is the discount factor, $c_{i,t}$ denotes consumption, and P_t the aggregate level of pollutants generated by the production of intermediates $y(i)$ using polluting energy services. We assume that aggregate pollution is triggered by the degree to which intermediate producers adopt the polluting technology. In equilibrium, we will show that there exists a threshold sector $J \in (0,1)$ below which only polluting energy services are used and above which only clean energy services are employed while sector J is indifferent. We therefore assume that P_t is an increasing function in J and that $P_t = J_t$. The parameter $\mu > 0$ steers the magnitude of the disutility derived from a polluted environment.[5] In equilibrium, the rate of time preference $\frac{1-\rho}{\rho}$ must be equal to the interest rate, such that $\rho = \frac{1}{1+r_t}$ for all t. We assume further that households can borrow and lend freely abroad at the world interest rate, i.e. $r_t = \bar{r}$ at any period in time and $\rho = \frac{1}{1+\bar{r}} = \frac{1}{R}$.

[5] The disutility derived from P_t is increasing in a quadratic fashion. This can be rationalised for instance by a convex damage function. Moreover, it ensures an interior solution to this problem. Pollution could be connected to many other variables of the model but all feasible combinations will also include J and thus the same set of deep parameters. Hence $P_t = J_t$ is a feasible and tractable shortcut.

Households accumulate wealth b_j, receive dividends from energy suppliers, $\pi_{j,t}$, and finance the set-up costs f_j for green and polluting energy suppliers being active in $t+1$

$$b_{i,t+1} - b_{i,t} = w_{i,t} + \bar{r} b_{i,t} + \tilde{\pi}_{i,t} - c_{i,t} - f_{i,t}. \tag{7}$$

Noting that aggregated set-up costs equal the number or firm entries in $t+1$ times sector specific fixed costs F_j aggregation over all households yields

$$B_{t+1} - B_t = w_{p,t} L_p + w_{c,t} L_c + \bar{r} B_t + N_{c,t}\pi_{c,t} + N_{d,t}\pi_{d,t} - C_t - N_{c,t+1}F_c - N_{p,t+1}F_p, \tag{8}$$

where C_t denotes aggregate consumption.

The government seeks to maximise aggregate welfare, but as outlined earlier we intend to examine the effects of politically motivated short-sighted governments that do not fully take into account the long-run consequences of their actions. The simplest way to incorporate this aspect into our model is to assume that at any time t the government announces a subsidy $s_{a,t}$ paid out in $t+1$ when the firms are active (see also figure 4 for a graphical presentation of the time line of events). The government maximises

$$W_t^g = \sum_{\tau=t}^{t+1} \rho^{\tau-t} \Big\{ C_\tau - \mu P_\tau^2 \Big\}, \tag{9}$$

subject to (8). We assume that the economy is in steady state and that the trade surplus is zero.[6] In order to ease the subsequent discussion, we assume that the domestic capital stock is owned by foreign agents only. This assumption helps us to focus on the most crucial channels when we turn to the government's problem. The households' optimisation problem is solved as soon as the government has implemented its preferred policy regarding the announced subsidy and the one it seeks to implement in $t+1$, i.e. $\{s_{a,t}, s_{t+1}\}$.

3.3 Equilibrium

Given the underlying specification of households' preferences, their savings decision is solved as soon as the equilibrium of the production side of the economy has been established on which

[6] This implies that the economy does not accumulate claims nor debts against the rest of the world and that GDP equals GNP. Note that this is a reasonable assumption since transversality excludes Ponzi games as well as a sustained accumulation of claims against the rest of the world.

the government imposes a subsidy on green energy services.

Profit maximising demand for energy services in the intermediate sector reads

$$x_c(i) = \left(\frac{\alpha \cdot p(i) \cdot (i)^\alpha}{p_{x_c}}\right)^{\frac{1}{1-\alpha}} \tilde{a}_c(i) \tag{10}$$

$$x_p(i) = \left(\frac{\alpha \cdot p(i) \cdot (1-i)^\alpha}{p_{x_p}}\right)^{\frac{1}{1-\alpha}} \tilde{a}_p(i), \tag{11}$$

where the index ω_j can be omitted because of the usual symmetry properties across sectors and types.

Profits of a typical x_j-supplier are given by $\pi_{x_c} = [p_{x_c} - c_{x_c}] \int_0^1 x_c(i)di$ and $\pi_{x_p} = [p_{x_p} - c_{x_p}] \int_0^1 x_p(i)di$, where c_{x_j} denotes the marginal production costs of x_j, such that all monopolists set the same profit maximising price $p_{x_j} = \frac{c_{x_j}}{\alpha}$.

The prices for intermediates $y(i)$ are given by

$$p(0) = p(i) \cdot (1-i)^\alpha \tag{12}$$

$$p(1) = p(i) \cdot (i)^\alpha, \tag{13}$$

such that equilibrium profits of x_j-suppliers are obtained as

$$\pi_{x_c} = \alpha \cdot p(1) \cdot (\tilde{A}_c)^{1-\alpha} \cdot (l_c)^{\alpha\beta} \cdot a_{c,x}^{\alpha(1-\beta)} - w_c \cdot l_c - R \cdot \tilde{a}_{c,x} \tag{14}$$

$$\pi_{x_p} = \alpha \cdot p(0) \cdot (\tilde{A}_p)^{1-\alpha} \cdot (l_p)^{\alpha\beta} \cdot e^{\alpha(1-\beta)} - w_p \cdot l_p - p_e \cdot e, \tag{15}$$

where p_e denotes the world market price for fossil energy. The rental price for equipment equals R. Wages in sector $j = c, p$ are captured by w_j and $\tilde{A}_j$ represents the aggregate amount of physical capital in either sector. Energy suppliers enter the market until the subsequent zero-profit condition is met

$$\frac{1}{R}(p_{x_j} - c_{x_j})x_j = F_j. \tag{16}$$

Eq. (16) determines the number of firm entries reflected by the range of available energy services N_j

$$N_c = \left(\frac{1-\alpha}{\alpha RF_c}\right)^{\frac{1-\alpha(1-\beta)}{\alpha\beta}} \left(\frac{1-\beta}{R}\right)^{\frac{1-\beta}{\beta}} \left(\alpha^2 p(1)(\tilde{A}_c)^{1-\alpha}\right)^{\frac{1}{\alpha\beta}} L_c \tag{17}$$

$$N_p = \left(\frac{1-\alpha}{\alpha RF_p}\right)^{\frac{1-\alpha(1-\beta)}{\alpha\beta}} \left(\frac{1-\beta}{p_e}\right)^{\frac{1-\beta}{\beta}} \left(\alpha^2 p(0)(\tilde{A}_p)^{1-\alpha}\right)^{\frac{1}{\alpha\beta}} L_p. \tag{18}$$

In light of the above relationships, the range of available energy services is increasing in the (effective) market size as captured by $\left(\alpha^2 p(0)(\tilde{A}_p)^{1-\alpha}\right)^{\frac{1}{\alpha\beta}} L_p$ and $\left(\alpha^2 p(1)(\tilde{A}_c)^{1-\alpha}\right)^{\frac{1}{\alpha\beta}} L_c$. These trigger the demand for x_j of each sector i and thus profits π_{x_j} of energy suppliers. N_j is in contrast negatively related to fixed costs F_j.

Wages of workers employed by an x_j-producer are obtained as

$$w_c = \beta\left(\frac{1-\beta}{R}\right)^{\frac{\alpha(1-\beta)}{1-\alpha(1-\beta)}} \left(\alpha^2 p(1)(\tilde{A}_c)^{1-\alpha}\right)^{\frac{1}{1-\alpha(1-\beta)}} (l_c)^{\frac{\alpha-1}{1-\alpha(1-\beta)}} \tag{19}$$

$$w_p = \beta\left(\frac{1-\beta}{p_e}\right)^{\frac{\alpha(1-\beta)}{1-\alpha(1-\beta)}} \left(\alpha^2 p(0)(\tilde{A}_p)^{1-\alpha}\right)^{\frac{1}{1-\alpha(1-\beta)}} (l_p)^{\frac{\alpha-1}{1-\alpha(1-\beta)}}. \tag{20}$$

Finally, intermediate producers aggregate demand for equipment writes

$$\tilde{A}_c = \alpha^{\frac{1-2\alpha\beta}{\tilde{\alpha}}} p(1)^{\frac{1}{\tilde{\alpha}}} \left(\frac{1-\alpha}{R}\right)^{\frac{\alpha\beta}{\tilde{\alpha}}} \left(\frac{1-\beta}{R}\right)^{\frac{\alpha(1-\beta)}{\tilde{\alpha}}} \left(\frac{1-\alpha}{\alpha RF_c}\right)^{\frac{1-\alpha}{\tilde{\alpha}}} (L_c)^{\frac{\alpha\beta}{\tilde{\alpha}}} \tag{21}$$

$$\tilde{A}_p = \alpha^{\frac{1-2\alpha\beta}{\tilde{\alpha}}} p(0)^{\frac{1}{\tilde{\alpha}}} \left(\frac{1-\alpha}{R}\right)^{\frac{\alpha\beta}{\tilde{\alpha}}} \left(\frac{1-\beta}{p_e}\right)^{\frac{\alpha(1-\beta)}{\tilde{\alpha}}} \left(\frac{1-\alpha}{\alpha RF_p}\right)^{\frac{1-\alpha}{\tilde{\alpha}}} (L_p)^{\frac{\alpha\beta}{\tilde{\alpha}}}, \tag{22}$$

with $\tilde{\alpha} = \alpha(1+\beta) - 1$.

As has been outlined earlier, energy services are subject to sector specific productivities in the production process of intermediates. In equilibrium, this feature is responsible for the segregation of sectors as follows, a specific sector is producing only with either polluting energy or clean energy, although each intermediate could conceptually be produced with either type of energies. The interesting implication of this result is that there exists a threshold sector $J \in (0,1)$ determined by

$$p(0)(1-J)^{-\alpha} = p(1)J^{-\alpha}. \tag{23}$$

The above expression states that the production of intermediate $y(J)$ is equally profitable with x_p or x_c implying that

$$J = \left[1 + \left(\frac{F_p}{F_c}\right)^{\frac{1-\alpha}{\bar{\alpha}}} \left(\frac{p_e}{R}\right)^{\frac{\alpha(1-\beta)}{\bar{\alpha}}} \left(\frac{L_c}{L_p}\right)^{\frac{\alpha\beta}{\bar{\alpha}}}\right]^{-1}, \tag{24}$$

with $\bar{\alpha} = \alpha(2+\beta) - 1$.

Obviously, J is inversely related to those factors that reduce the relative profitability of x_p-producers compared to x_c-producers, i.e. relative fixed costs $\frac{F_p}{F_c}$, the price ratio of fossils and equipment for the clean technology $\frac{p_e}{R}$, as well as the employment ratio in the clean and polluting sector $\frac{L_c}{L_p}$. Observing that x_p has a higher productivity in low-i sectors while x_c exhibits a higher productivity in high-i sectors this reasoning makes intuitively sense. Thus, if the relative profitability of polluting energy services shrinks the zero-profit condition (16) which governs the market entry for energy suppliers induces a relative increase in the number green relative to polluting energy suppliers $\frac{N_c}{N_p}$ such that the index J as established by (24) must shrink. This implies that the economy becomes greener, in the sense that a higher range of intermediates $y(i)$ is produced with clean energy.

Finally, the prices for intermediates produced with polluting or green energy services can be obtained as

$$p(0) = \exp(-\alpha)J^{-\alpha} \tag{25}$$

$$p(1) = \exp(-\alpha)(1-J)^{-\alpha}. \tag{26}$$

In the subsequent section we discuss the implications of governmental decisions and announcements regarding a subsidy on green energy services.

3.4 Policies

The government in office observes the above equilibrium and seeks to increase social welfare by announcing a subsidy on fixed costs of clean energy suppliers. It is instructive to look first at the implications resulting from a scenario without any uncertainties regarding the type of government being in office.

No uncertainties Let's assume that the government in office is able to commit itself to the implementation of its announced subsidy in the subsequent period, and that there are no uncertainties regarding the government's preferences, such that $s_{a,t} = s_{t+1}/R$. The zero profit condition (16) implies that $F_c[1 - s_{a,t}] = \frac{\pi_{c,t+1}}{R}$ and $F_p = \frac{\pi_{p,t+1}}{R}$, such that the optimisation problem of the government boils downs to[7]

$$\max_{s_{t+1}} W_t^g = \Big\{ w_{p,t}L_p + w_{c,t}L_c + N_{c,t}\pi_{c,t} + N_{d,t}\pi_{d,t} - \mu P_t^2 + \frac{1}{R}\Big[w_{p,t+1}L_p + w_{c,t+1}L_c - s_{t+1}N_{c,t+1}F_c - N_{p,t+2}F_p - N_{c,t+2}F_c(1 - s_{a,t+1}) - \mu P_{t+1}^2 \Big] \Big\} \tag{27}$$

The first-order condition to this problem can be expressed as

$$\underbrace{\frac{\partial w_{p,t+1}}{\partial s_{t+1}}}_{>0} L_p + \underbrace{\frac{\partial w_{c,t+1}}{\partial s_{t+1}}}_{>0} L_c - \Big[N_{c,t+1} + s_{t+1} \underbrace{\frac{\partial N_{c,t+1}}{\partial s_{t+1}}}_{>0} \Big] F_c - 2\mu P_{t+1} \underbrace{\frac{\partial P_{t+1}}{\partial s_{t+1}}}_{<0} = 0 \tag{28}$$

which determines the preferred subsidy $\bar{s}$ both announced and implemented by the government.

Proposition 1 (no uncertainties). *There exists a unique subsidy $\bar{s} > 0$ - announced and implemented - for green energy suppliers that maximises the constraint welfare function of the government (27), where $\bar{s}$ is increasing in μ, i.e. $\frac{\partial \bar{s}}{\partial \mu} > 0$.*

The proof follows from (17)-(22). The last term is negative. As J [see (24)] is shrinking in response to s_{t+1}, wages in the polluting sector must increase, such that the first term is positive. At the same time $p(1)$ [see (25)] is shrinking but $N_{c,t+1}$ is increasing. Since the price effect is smaller than the induced market size effect, wages in the clean sector increase as well and by more compared to the polluting sector. Thus, (27) is hump-shaped in s_{t+1} implying that there is a unique $\bar{s} > 0$ satisfying (28). A greater μ increases the weight of the last term in (28), such that $\frac{\partial \bar{s}}{\partial \mu} > 0$.

[7] We assume that there hasn't been announced any subsidy in the previous period.

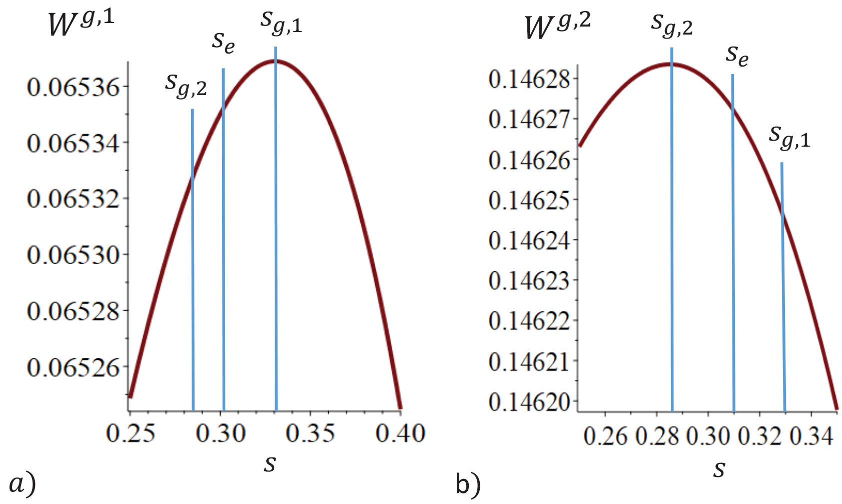

Figure 3: a): welfare of type-1 government with $\mu = 0.35$, $s_{g,1} = .3302$; b) welfare of type-2 government with $\mu = 0.15$ $s_{g,2} = .2850$. $p_1 = 0.6$ such that $s_e = 0.3122$. Parameters: $\alpha = 0.9; \beta = 0.5; F_c = 1; F_p = 1; p_e := .1; r := .06; \rho := 0.98; L_c := 1/3; L_p := 2/3$

The pay-off maximising subsidy $\bar{s}$ implies

$$W_t^{g,\bar{s}} = V_t^{g,\bar{s}} + \frac{1}{R} V_{t+1}^{g,\bar{s}} \tag{29}$$

with

$$V_t^{g,\bar{s}} = w_{p,t} L_p + w_{c,t} L_c + N_{c,t}\pi_{c,t} + N_{d,t}\pi_{d,t} - \mu P_t^2 \tag{30}$$

and

$$V_{t+1}^{g,\bar{s}} = w_{p,t+1}^{\bar{s}} L_p + w_{c,t+1}^{\bar{s}} L_c - \bar{s} N_{c,t+1}^{\bar{s}} F_c - N_{p,t+2} F_p - N_{c,t+2} F_c (1 - s_{a,t+1}) - \mu (P_{t+1}^{\bar{s}})^2 \tag{31}$$

Uncertainties regarding the type of the government Assume households and firms are unable to observe the type of the government in office. Specifically, we assume that the government's environmental preferences are unobservable but the audience knows that there are two types h of governments, i.e. $h = 1, 2$. A type-1 government shares the preferences of households ($\mu_{g,1} = \mu$) while type 2 attaches a lower weight to the environment ($\mu_{g,2} < \mu$).[8] In

[8]This can be motivated by a business cycle shock or lobbying pressure to which the type-1 government is immune. We discuss more general assumptions in Section 4.

light of Proposition 1, the preferred subsidy of the type-1 government is

$$s_{g,1} = \bar{s} > s_{g,2} \tag{32}$$

as $\mu_{g,2} < \mu_{g,1} = \mu$, see also Figure 3.

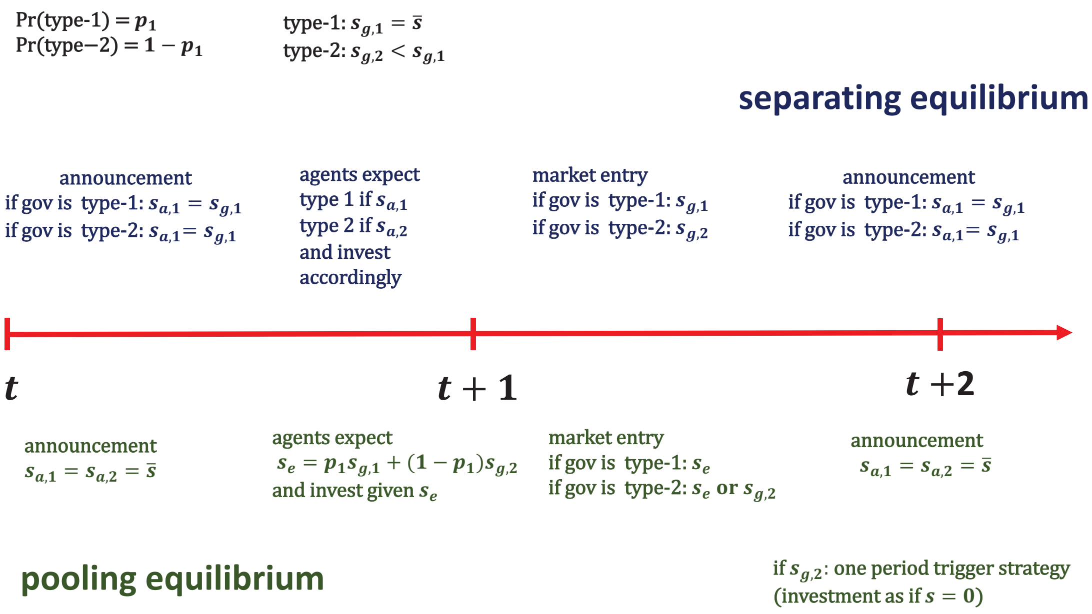

Figure 4: Timeline for separating and pooling equilibria

If both governments announce the same subsidy (pooling equilibrium), see Figure 4, agents have no additional information to update the prior probabilities that nature has assigned to both types of the government. If the probability that the government is of type-1 is $p_1 \in (0, 1)$ agents (posterior) beliefs are consistent according to Bayes rule if they believe that the probability that the government is of type-1 is p_1. Since the type-1 government shares the same preferences with the households, it has no incentive to announce a subsidy different to $\bar{s}$. Hence, the only candidate for a pooling equilibrium is that the type-2 government announces also $\bar{s}$. In this sense, the announcement of the government in office does not reveal its identity such that agents expect

$$s_e = p_1 \bar{s} + (1 - p_1) s_{g,2} \tag{33}$$

which implies that $\bar{s} > s_e > s_{g,2}$.

Thus, in period t agents invest in fixed costs expecting a subsidy of s_e in $t+1$ which has repercussions on the implemented subsidy in $t+1$ if the government is of type-1

Proposition 2. *If the government in office is of type-1, it will implement a subsidy $s_{g,1} = s_e < \bar{s}$.*

This is an interesting result in the sense that the type-1 government deviates from its announcement. The reason is that decisions regarding the market entry of energy suppliers have been taken in period t given the expectations at that date. These decisions determine the number of firm entries and the ranges of available energy services N_j in $t+1$. Since, a subsidy exceeding s_e is unable to affect the market entry in $t+1$, the type-1 government just implements what the agents expected the period before. Hence, the welfare loss is increasing in the probability that the government is of type-2 and in $\mu_{g,1} - \mu_{g,2}$, i.e. in the difference of environmental preferences (see also Figure 3).

Proposition 3. *If the government in office is of type-2, it will implement either s_e or deviate to its preferred subsidy $s_{g,2} < s_e < \bar{s}$.*

If the type-2 government deviates in $t+1$ to $s_{g,2}$, agents will respond in $t+2$ with a one-period trigger strategy and ignore the announcement of the government made in $t+1$. Under these circumstances, the pay-off amounts to

$$W_{t+1}^{g,2,d} = V_{t+1}^{g,2,s_{g,2}} + \frac{1}{R} V_{t+2}^{g,2,s=0} \tag{34}$$

where the superscript d on the left-hand side indicates that the type-2 government deviates to its preferred subsidy $s_{g,2}$ while any announcement made in this period is meaningless in the sense that firms act in terms of period $t+2$ as if $s=0$. Moreover,

$$\begin{aligned} V_{t+1}^{g,2,s_{g,2}} &= w_{p,t+1}^{s_{g,2}} L_p + w_{c,t+1}^{s_{g,2}} L_c + \pi_{p,t+1}^{s_{g,2}} N_{p,t+1}^{s_{g,2}} + \pi_{c,t+1}^{s_{g,2}} N_{c,t+1}^{s_{g,2}} - N_{p,t+2}^{s=0} F_p - N_{c,t+2}^{s=0} F_c \\ &- \mu_{g,2} (P_{t+1}^{s_{g,2}})^2 \end{aligned} \tag{35}$$

and

$$V_{t+2}^{g,2,s=0} = w_{p,t+2}^{s=0} L_p + w_{c,t+2}^{s=0} L_c + \pi_{p,t+2}^{s=0} N_{p,t+2}^{s=0} + \pi_{c,t+2}^{s=0} N_{c,t+2}^{s=0} - \mu_{g,2} (P_{t+2}^{s=0})^2 \tag{36}$$

If the government does not deviate and implements s_e, period pay-offs are identical such that

$$W_{t+1}^{g,2,s_e} = V_{t+1}^{g,2,s_e} + \frac{1}{R} V_{t+2}^{g,2,s_e} \tag{37}$$

Hence, we can establish the following proposition

Proposition 4. *A type-2 government deviates if*

$$W_{t+1}^{g,2,d} \geq W_{t+1}^{g,2,s_e} \tag{38}$$

$$\Rightarrow V_{t+1}^{g,2,s_{g,2}} - V_{t+1}^{g,2,s_e} \geq \frac{1}{R}\left\{V_{t+2}^{g,2,s_e} - V_{t+2}^{g,2,s=0}\right\} \tag{39}$$

The left-hand side of the above expression is always greater than zero. The right-hand side in turn may be positive or negative depending on the difference between $s_{g,2}$ which maximises a type-2 government's pay-off and s_e. Since $s_e > s_{g,2}$, there exist a critical s_e above which the right-hand side turns negative. This is likely to happen when the probability that the government in office is actually a type-1 government is high and environmental preferences of a type-2 government are comparatively low.

So far, we can summarise our results as follows: a type-1 government has no incentive to deviate from its announcement. The probability that the government in office is actually of type-2 pushes, however, agents' expected subsidy s_e below $s_{g,1}$ such that a type-1 government implements in $t+1$ what agents expect, i.e. s_e. In this sense, the mere possibility of a type-2 government in office reduces the expected subsidy and reduces market entry below the socially optimal level. If the type-2 government makes the same announcement, the announced subsidy does not reveal the type of the government in office. When it comes to the implementation of the announcement, a type-2 government might have an incentive to deviate from the expected subsidy.

We now analyse whether a type-2 government might have an incentive to reveal its identity by announcing its preferred subsidy before agents invest. In this separating equilibrium the announcement of the subsidy would reveal the identity of the government. In such a case, agents' beliefs are in light of Bayes rule consistent if they believe that $Pr(type_1|\bar{s}) = 1$ and $Pr(type_2|\bar{s}) = 0$.

Since $s_{g,2}$ maximises a type-2 government's pay-off, only the following relationships depending on weather there is an incentive to deviate can arise

$$W_{t+1}^{g,2,s_{g,2}} > W_{t+1}^{g,2,s_e} > W_{t+1}^{g,2,d} \tag{40}$$

$$W_{t+1}^{g,2,s_{g,2}} > W_{t+1}^{g,2,d} > W_{t+1}^{g,2,s_e}. \tag{41}$$

Hence we can conclude that a type-2 government prefers to reveal its identity before agents invest.

Proposition 5. *Both types of governments prefer to reveal their identities before agents invest.*

From the perspective of a type-2 agent, the possibility to deviate is only comparatively better if the initial announcement was compared to the preferred subsidy $s_{g,2}$ too far-fetched. Therefore, the type-2 government has no incentive to mimic the announcement of the type-1 agent. For symmetric reasons, the type-1 government will never mimic the type-2 government by announcing a lower subsidy which would drive it even further away from its most preferred level. We thus can expect that any announcement of a government in office will reveal its identity in equilibrium.

4 Discussion

The theoretical framework indicates two important findings. First, welfare-optimising governments have an inherent incentive to reveal their true identity and signal the actual policy measure they are aiming for. Second, such a signal is then an important information for entrepreneurs planning their investment for the subsequent periods. This leads to industry development before the policy is in place. In light of the model's results we are confident about the interpretation of our empirical findings. In particular, the first major policy, the feed-in policy KEV, seems to have supported the built-up of the industry already before its enactment. Our findings, thus, suggest that policy may serve as a credible signal to the industry and that there is no incentive to mimic a government with strong environmental preferences. Yet, this may not be the case for other legislations and institutional settings. For example, the incentive to send wrong signals may be different, if the announcement is decisive for winning the elections and stay in office. Examples include the announcement of the German government to abandon its nuclear power strategy in response to the Fukushima disaster (Wiesman, 2011) and the associated vast increase in popularity of the Green party, or the most recent adjustment of the high-speed train project (HS-2) of the conservative government in the UK which was an integral part of its election campaign (Pidd, 2021).

We extend our model slightly by a government that is elected by the majority of the population based on a promise in terms of its intentions regarding the subsidisation of clean energy producers. Once in office the government announces its policy s_t^a as we have discussed it before in figure 4.[9] Let's assume the government's utility U^g depends on its welfare function $W_t^{g_j,s_{g,m}}$, with $j,m = 1,2$ such that j represents the type of the government and m the type of the subsidy. Moreover, utility of being still in office after the next elections is denoted by E_{t+1}^1, or E_{t+1}^0 in case the government is not re-elected. Obviously, $E_{t+1}^1 > E_{t+1}^0$. Without further loss in generality $E_{t+1}^0 = 0$ and

$$U_t^{g_j} = (1-\nu)W_t^{g_j,s_{g,m}} + \nu E_{t+1}^l, \qquad l = 0,1; \nu \in [0,1) \tag{42}$$

Apparently, $\nu = 0$ represents the theory discussed so far. For any $0 < \nu < 1$, the government will announce and implement s_1 (s_2) if it is a type-1 (type-2) government elected by a type-1 (type-2) median voter. We hence will have to look at the mixed cases.

(1) Type-2 population but type-1 government The electorate prefers a subsidy s_2. The government in office had promised to implement this subsidy. If it implements this subsidy, the government will be re-elected at end of the next period. Hence,

$$U_t^{g_1}(s_{g,2}, E^1) = (1-\nu)W_t^{g_1,s_{g,2}} + \nu E_{t+1}^1 \tag{43}$$

If the government decides to announce and implement s_1 instead

$$U_t^{g_1}(s_{g,1}, E^0) = (1-\nu)W_t^{g_1,s_{g,1}} \tag{44}$$

As $W_t^{g_1,s_{g,2}} < W_t^{g_1,s_{g,1}}$, the government has an incentive to implement the higher subsidy, i.e. breaking its promise made ahead of the elections, if

$$(1-\nu)W_t^{g_1,s_{g,2}} + \nu E_{t+1}^1 < (1-\nu)W_t^{g_1,s_{g,2}}. \tag{45}$$

[9] Elections take place at the end of period $t-1$ and $t+1$.

This is the case, if

$$\nu < \nu_1^{crit} = \frac{W_t^{g_1,s_{g,1}} - W_t^{g_1,s_{g,2}}}{W_t^{g_1,s_{g,1}} - W_t^{g_1,s_{g,2}} + E_{t+1}^1} \tag{46}$$

The above relationship states that there exists a critical weight a government attaches to wining the elections compared to its social welfare function below which the government in office deviates from its promise to the electorate and implements the higher subsidy s_1. This threshold is adversely affected by the utility of staying in office but positively affected by the welfare differential. For $\nu \geq \nu_1^{crit}$, the government implements s_2.[10]

(2) Type-1 population but type-2 government The government in office has promised to the electorate s_1 ahead of the elections. As $W_t^{g_2,s_{g,1}} < W_t^{g_2,s_{g,2}}$, the government has an incentive to implement s_2 if

$$\nu < \nu_2^{crit} = \frac{W_t^{G_2,s_{g,2}} - W_t^{g_2,s_{g,1}}}{W_t^{g_2,s_{g,2}} - W_t^{g_2,s_{g,1}} + E_{t+1}^1} \tag{47}$$

Again, a departure from promises made ahead of the election becomes more likely if the utility differential between the two policy options is high or the utility from staying in office is low. In either cases, the government can only compromise the electorate in terms of the promises made during the election campaign, but by revealing its identity through the announcement after the election, entrepreneurs know what they can expect.

5 Conclusion

The starting point of this paper was the observation that, in light of long-term climate policy targets, policy announcements aiming to support the energy transition and their impact on economic activity are under-researched. In a first step we explored empirically whether we can identify an impact of policy announcements on green energy entrepreneurship. In this context, we tested whether credible signals about future policies influence the number of firm entries. To do so, we use a new dataset compiled from the Swiss commercial registry to analyze the number of new firm registrations related to green energy products and services. Our study reveals a highly significant relationship between information on future policies and firm entries. Credible

[10] Gersbach and Kleinschmitt (2004) suggest under these circumstances rejection/support rewards.

policy information seems to work as an important signal that can foster (or depress) industry built-up.

In a second step we developed a theoretical model to gain more clarity about the economic mechanisms behind the credibility of policy announcements related to future policy intentions regarding the energy transition. Our model comprises firms investing in their technology given their expectations about a future policy. At this stage entrepreneurs are unable to observe the type of the government, which is the degree of its environmental preferences. We have shown that from the perspective of a dirty government in equilibrium a pooling strategy exists by mimicking the clean government, but that it is dominated by the separating strategy such that both types of governments reveal their identity by announcing an appropriate subsidy before firms invest. Thus, a dirty government has no incentive to mimic a green policy once in office. Clean governments on the other hand can use policy information as credible signals to spur the transition to green technologies. This increases the credibility of announcements in the sense that environmental policies linked to subsidies of green technologies can serve as a credible signal for governments in office. We also have looked at governments attaching a certain value on staying in office. Under these circumstances deviations in terms of the promise made to the electorate are possible, but if this happens investors have clarity about the nature of the government and adjust their investment decisions accordingly.

Overall, our analysis complements existing literature on entry decision and industry formation and suggests a interesting implication for policy-making: on the one hand, governments are able to signal a policy commitment towards entrepreneurs and thereby spur the development of a market simply by providing information. Information can then be strategically used to shape a sector's expectations, similar to strategic communication as a widely recognized instrument in monetary policy. On the other hand and, again, similar to findings from the monetary policy information literature, signals about a less beneficial policy likewise influence expectations. Thus, while transparent information can be considered as beneficial in itself, policymakers ought to be aware of the potentially positive and negative effects of announced policies.

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A Empirical Analysis

Data

The definition of the keywords for the firm search in the online registry of the Swiss commercial registry followed a three-step approach. First, we analysed a set of typical solar firm descriptions and identified the two most prevalent keywords: solar and renewable (in the three languages German, French and Italian). We then extracted the number of firms for each keyword separately and performed random checks whether the included firms indeed belong to the respective sector. We had to adapt the keyword for solar (from solar∗ to solar) to exclude tanning salons which would have been included with solar∗. Finally, we merged the two datasets of the firms identified with each keyword and removed duplicates. A similar procedure was applied for the control sector phone. The final keywords are as following:

Sector	Language	Keyword	Number of firms
Green energy firms			
	German	erneuerbar∗	1’206 firms
		solar	604 firms
	French	renouvelable∗	644 firms
		solaire	274 firms
	Italian	rinnovabile∗	90 firms
		solare	100 firms
Total		(after merge and removal of duplicates)	2’676 firms
Phone firms			
	German/Italian	∗telefon∗	2’178 firms
	French	∗phone∗	969 firms
Total		(after merge and removal of duplicates)	3’094 firms

Table 3: Number of firms per keyword and language.

Policy Dates

Date	Announcement of Policy Measure	Enactment
23.3.2007	KEV	
01.01.2009		KEV
August 2011	New transparency guidelines	
01.10.2011		New transparency guidelines
21.06.2013	EIV	
01.04.2014		EIV

Table 4: Announcements and enactments of new major policies supporting green energy use in Switzerland.

Additional regression analyses

	CountAv					
	(1)	(2)	(3)	(4)	(5)	(6)
industrysolar	0.362	0.362*	0.362	0.362*	0.362	0.362*
	(0.189)	(0.175)	(0.193)	(0.178)	(0.192)	(0.177)
kev1	−0.186	−1.690***	−0.186	−1.944***	−0.186	−1.909***
	(0.267)	(0.419)	(0.272)	(0.421)	(0.272)	(0.420)
kev2	−0.410	−2.391***	−0.190	−2.658***	−0.190	−2.574***
	(0.237)	(0.618)	(0.235)	(0.628)	(0.234)	(0.625)
eiv1	0.195	0.149	0.195	0.070	0.195	0.124
	(0.408)	(0.383)	(0.415)	(0.391)	(0.415)	(0.390)
eiv2	−0.041	0.181	0.030	−0.067	−0.024	0.176
	(0.274)	(0.350)	(0.310)	(0.351)	(0.295)	(0.373)
trans1	−1.426	−1.204	−0.240	−0.167	−0.240	−0.088
	(1.120)	(1.053)	(1.097)	(1.035)	(1.096)	(1.032)
trans2	−1.138**	−1.133**	0.048	−0.241	0.048	−0.057
	(0.429)	(0.415)	(0.303)	(0.359)	(0.303)	(0.356)
industrysolar:kev1	3.197***	3.197***	3.197***	3.197***	3.197***	3.197***
	(0.378)	(0.349)	(0.385)	(0.356)	(0.385)	(0.354)
industrysolar:kev2	5.924***	5.924***	5.924***	5.924***	5.924***	5.924***
	(0.326)	(0.301)	(0.332)	(0.306)	(0.331)	(0.305)
industrysolar:eiv1	−1.892**	−1.892***	−1.892**	−1.892***	−1.892**	−1.892***
	(0.576)	(0.532)	(0.587)	(0.542)	(0.587)	(0.540)
industrysolar:eiv2	−2.995***	−2.995***	−2.995***	−2.995***	−3.143***	−3.143***
	(0.388)	(0.358)	(0.395)	(0.365)	(0.417)	(0.384)
industrysolar:trans1	1.441	1.441	1.441	1.441	1.441	1.441
	(1.523)	(1.407)	(1.552)	(1.433)	(1.550)	(1.428)
industrysolar:trans2	1.120**	1.120**	1.120**	1.120**	1.120**	1.120**
	(0.421)	(0.389)	(0.429)	(0.396)	(0.429)	(0.395)
industrysolar:e2050					0.512	0.512
					(0.467)	(0.431)
fukushima	1.405***	1.354***				
	(0.365)	(0.363)				
paris			−0.115	−0.062		
			(0.218)	(0.261)		
e2050					−0.059	0.229
					(0.330)	(0.400)
Seasonal Controls		✓		✓		✓
Economic Controls		✓		✓		✓
Constant	1.012***	−5.595*	1.012***	−4.732	1.012***	−5.586*
	(0.134)	(2.336)	(0.136)	(2.424)	(0.136)	(2.417)
Observations	400	400	400	400	400	400
R^2	0.858	0.884	0.853	0.880	0.854	0.881
Adjusted R^2	0.853	0.875	0.848	0.870	0.848	0.871
Residual Std. Error	1.061 (df = 385)	0.980 (df = 370)	1.080 (df = 385)	0.998 (df = 370)	1.080 (df = 384)	0.995 (df = 369)
F Statistic	166.760*** (df = 14; 385)	97.168*** (df = 29; 370)	159.697*** (df = 14; 385)	93.195*** (df = 29; 370)	149.406*** (df = 15; 384)	90.792*** (df = 30; 369)

Note: *p<0.05; **p<0.01; ***p<0.001

Table 5: DiD regressions with controls. Columns 1 and 2 controlling for Fukushima, columns 3 and 4 for the Paris Agreement and columns 5 and 6 for the Swiss energy law revision

B Mathematical Appendix

A.1 test

$$\begin{aligned}\pi_y(i) &= p(i)y(i) - \int_0^{N_{p,t}} p_{x_p}(\omega_p)x_{p,t}(i,\omega_p)d\omega_p - \int_0^{N_{c,t}} p_{x_c}(\omega_c)x_{c,t}(i,\omega_c)d\omega_c \\ &- \bar{R}[\tilde{a}_{p,t}(i) + \tilde{a}_{c,t}(i)] \end{aligned} \tag{A.1}$$

Since energy services (x) are subject to sector specific productivities [see (3)] in the sense that the productivity of polluting energy services decreases with the sector index i and vice versa for clean energy services, there exists a threshold sector $J \in [0, 1]$ above (below) which only clean (polluting) energy services are employed. From (A.1) the value marginal product of energy service equals their price if - we omit the presentation of the clean sectors which is symmetric to the polluting sectors

$$p_{x_p}(\omega_p) = \alpha p(i)x_p(\omega_p)^{\alpha-1}\tilde{a}_p(i)^{1-\alpha}(1-i)^{\alpha} \tag{A.2}$$

which determines the profit maximising demand schedule (11) [and similarly (10)].

A.2 Derivation of $p(0)$ and $p(1)$

Imposing the standard symmetry conditions on the production of intermediates, we can drop the indices ω_p, ω_c such that prices from energy serves are equal to the usual markup over marginal production costs $p_{x_p} = \frac{c_{xp}}{\alpha}$ and $p_{x_c} = \frac{c_{x_c}}{\alpha}$. Demand for equipment is implicitly determined by

$$p(i)(1-\alpha)\tilde{a}_p(i)^{-\alpha}N_{p,t}[(1-i)x_p]^{\alpha} = \bar{R}. \tag{A.3}$$

Replacing prices for energy services and their quantities by (11) yields

$$(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}p(i)^{\frac{1}{1-\alpha}}N_{p,t}(1-i)^{\frac{\alpha}{1-\alpha}}c_{x_p}^{\frac{\alpha}{\alpha-1}} = \bar{R}. \tag{A.4}$$

As the above relationship also must hold for sector $i = 0$

$$(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}p(0)^{\frac{1}{1-\alpha}}N_{p,t}c_{x_p}^{\frac{\alpha}{\alpha-1}} = \bar{R}. \tag{A.5}$$

such that the last two equations imply

$$p(0)^{\frac{1}{1-\alpha}} = p(i)^{\frac{1}{1-\alpha}}(1-i)^{\frac{\alpha}{1-\alpha}} \tag{A.6}$$

$$p(i) = p(0)(1-i)^{-\alpha}. \tag{A.7}$$

For the green sectors we obtain symmetrically

$$p(i) = p(1)(i)^{-\alpha}. \tag{A.8}$$

A.3 Profits of energy producers

A supplier of energy service $x_j(\omega_p), j = c, p$ faces demand of sectors $i \in [0, J]$ or $[J, 1]$ depending on whether $j = c$ or $j = p$, such that

$$\pi_{x_p}(\omega_p) = \int_0^J p_{x_p}(\omega_p)x_p(i, \omega_p)di - w_p l_p(\omega_p) - p_E e_p(\omega_p) \tag{A.9}$$

Again, all energy services are produced and supplied under symmetric conditions, such that in light of (A.2)

$$\pi_{x_p} = \int_0^J \alpha p(i)x_p(i)^\alpha \tilde{a}_p(i)^{1-\alpha}(1-i)^\alpha di - w_p l_p - p_E e_p \tag{A.10}$$

Replacing $p(i)$ by (A.7) yields furthermore

$$\pi_{x_p} = \alpha p(0)x_p^\alpha \tilde{A}_p^{1-\alpha} - w_p l_p - p_E e_p \tag{A.11}$$

and symmetrically

$$\pi_{x_c} = \alpha p(1)x_c^\alpha \tilde{A}_c^{1-\alpha} - w_c l_c - \bar{R}k_c \tag{A.12}$$

A.4 Market entry of energy suppliers

Market entry of energy suppliers is triggered by the following zero-profit comdition

$$(p_{x_j} - c_{x_j})x_j = F_j \tag{A.13}$$

As $p_{x_j} = \frac{c_{x_j}}{\alpha}$

$$\frac{1-\alpha}{\alpha} c_{x_j} x_j = F_j \tag{A.14}$$

Cost minimisation implies that

$$c_{x_p} = \Big(\frac{w_p}{\beta}\Big)^{\beta} \Big(\frac{p_E}{1-\beta}\Big)^{1-\beta} \tag{A.15}$$

$$c_{x_c} = \Big(\frac{w_c}{\beta}\Big)^{\beta} \Big(\frac{\bar{R}}{1-\beta}\Big)^{1-\beta} \tag{A.16}$$

Hence

$$\frac{1-\alpha}{\alpha} \Big(\frac{w_p}{\beta}\Big)^{\beta} \Big(\frac{p_E}{1-\beta}\Big)^{1-\beta} (l_p)^{\beta} e^{1-\beta} = F_p \tag{A.17}$$

A profit maximum requires that $\frac{\partial \pi_{x_c}}{\partial l_p} = \frac{\partial \pi_{x_p}}{\partial k} = 0$ and $\frac{\partial \pi_{x_p}}{\partial l_p} = \frac{\partial \pi_{x_p}}{\partial e} = 0$ such that

$$k = \Big(\frac{\alpha^2 (1-\beta) p(1) \tilde{A}_c^{1-\alpha}}{\bar{R}}\Big)^{\frac{1}{1-\alpha(1-\beta)}} (l_c)^{\frac{\alpha\beta}{1-\alpha(1-\beta)}} \tag{A.18}$$

$$w_c = \beta \Big(\frac{1-\beta}{\bar{R}}\Big)^{\frac{\alpha(1-\beta)}{1-\alpha(1-\beta)}} \Big(\alpha^2 p(1) \tilde{A}_c^{1-\alpha}\Big)^{\frac{1}{1-\alpha(1-\beta)}} (l_c)^{\frac{\alpha-1}{1-\alpha(1-\beta)}} \tag{A.19}$$

$$e = \Big(\frac{\alpha^2 (1-\beta) p(0) \tilde{A}_p^{1-\alpha}}{p_E}\Big)^{\frac{1}{1-\alpha(1-\beta)}} (l_p)^{\frac{\alpha\beta}{1-\alpha(1-\beta)}} \tag{A.20}$$

$$w_p = \beta \Big(\frac{1-\beta}{p_E}\Big)^{\frac{\alpha(1-\beta)}{1-\alpha(1-\beta)}} \Big(\alpha^2 p(0) \tilde{A}_p^{1-\alpha}\Big)^{\frac{1}{1-\alpha(1-\beta)}} (l_p)^{\frac{\alpha-1}{1-\alpha(1-\beta)}} \tag{A.21}$$

Combining the last two equations with (A.17) and noting that full employment requires that $N_{p,t} l_p = L_p$ yields

$$\frac{1-\alpha}{\alpha} \Big(\frac{1-\beta}{p_E}\Big)^{\frac{\alpha(1-\beta)}{1-\alpha(1-\beta)}} \Big(\alpha^2 p(0) \tilde{A}_p^{1-\alpha}\Big)^{\frac{1}{1-\alpha(1-\beta)}} \Big(\frac{L_p}{N_{p,t}}\Big)^{\frac{\alpha\beta}{1-\alpha(1-\beta)}} = F_p \tag{A.22}$$

such that

$$N_{p,t} = \Big(\frac{1-\alpha}{\alpha F_p}\Big)^{\frac{1-\alpha(1-\beta)}{\alpha\beta}} \Big(\frac{1-\beta}{p_E}\Big)^{\frac{1-\beta}{\beta}} \Big(\alpha^2 p(0) \tilde{A}_p^{1-\alpha}\Big)^{\frac{1}{\alpha\beta}} L_p \tag{A.23}$$

and similarly

$$N_{c,t} = \Big(\frac{1-\alpha}{\alpha F_c}\Big)^{\frac{1-\alpha(1-\beta)}{\alpha\beta}} \Big(\frac{1-\beta}{\bar{R}}\Big)^{\frac{1-\beta}{\beta}} \Big(\alpha^2 p(1) \tilde{A}_c^{1-\alpha}\Big)^{\frac{1}{\alpha\beta}} L_c \tag{A.24}$$

A.5 Equipment

Profit maximising behaviour of $y(i)$-producers implies (A.25). Replacing $N_{p,t}$ and marginal production costs yields

$$(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}p(0)^{\frac{1}{1-\alpha}}\left(\frac{1-\alpha}{\alpha F_p}\right)^{\frac{1-\alpha(1-\beta)}{\alpha\beta}}\left(\frac{1-\beta}{p_E}\right)^{\frac{1-\beta}{\beta}}\left(\alpha^2 p(0)\tilde{A}_p^{1-\alpha}\right)^{\frac{1}{\alpha\beta}}L_p$$
$$\left[\left(\frac{w_p}{\beta}\right)^{\beta}\left(\frac{p_E}{1-\beta}\right)^{1-\beta}\right]^{\frac{\alpha}{\alpha-1}} = \bar{R}. \tag{A.25}$$

Replacing fanally w_p by (A.21) yields

$$\tilde{A}_p = \alpha^{\frac{1-2\alpha\beta}{\tilde{\alpha}}}p(0)^{\frac{1}{\tilde{\alpha}}}\left(\frac{1-\alpha}{\bar{R}}\right)^{\frac{\alpha\beta}{\tilde{\alpha}}}\left(\frac{1-\beta}{p_e}\right)^{\frac{\alpha(1-\beta)}{\tilde{\alpha}}}\left(\frac{1-\alpha}{\alpha F_p}\right)^{\frac{1-\alpha}{\tilde{\alpha}}}(L_p)^{\frac{\alpha\beta}{\tilde{\alpha}}} \tag{A.26}$$

and symmetrically,

$$\tilde{A}_c = \alpha^{\frac{1-2\alpha\beta}{\tilde{\alpha}}}p(1)^{\frac{1}{\tilde{\alpha}}}\left(\frac{1-\alpha}{\bar{R}}\right)^{\frac{\alpha\beta}{\tilde{\alpha}}}\left(\frac{1-\beta}{\bar{R}}\right)^{\frac{\alpha(1-\beta)}{\tilde{\alpha}}}\left(\frac{1-\alpha}{\alpha F_c}\right)^{\frac{1-\alpha}{\tilde{\alpha}}}(L_c)^{\frac{\alpha\beta}{\tilde{\alpha}}} \tag{A.27}$$

with $\tilde{\alpha} = \alpha(1+\beta)-1$.

A.6 Threshold sector J

Profit maximising behaviour in the in the final output secotr implies

$$y(i) = \frac{Y}{p(i)} \tag{A.28}$$

and therefore

$$\frac{y(1)}{y(0)} = \frac{p(0)}{p(1)} \tag{A.29}$$

Thus

$$\frac{p(0)}{p(1)} = \frac{N_{c,t}}{N_{p,t}}\left(\frac{p(1)}{p(0)}\right)^{\frac{\alpha}{1-\alpha}}\left(\frac{c_{x_p}}{c_{x_c}}\right)^{\frac{\alpha}{1-\alpha}}\frac{\tilde{a}_c(1)}{\tilde{a}_p(0)} \tag{A.30}$$

$$\left(\frac{p(0)}{p(1)}\right)^{\frac{1}{1-\alpha}} = \frac{N_{c,t}}{N_{p,t}}\left(\frac{c_{x_p}}{c_{x_c}}\right)^{\frac{\alpha}{1-\alpha}}\frac{\tilde{A}_c}{\tilde{A}_p}\frac{J}{1-J} \tag{A.31}$$

Replacing $\frac{N_{c,t}}{N_{p,t}}$ and $\frac{c_{x,p}}{c_{x,c}}$ yields

$$\left(\frac{p(0)}{p(1)}\right)^{\frac{1}{\alpha\beta}} = \left(\frac{F_p}{F_c}\right)^{\frac{1-\alpha}{\alpha\beta}} \left(\frac{p_E}{\bar{R}}\right)^{\frac{1-\beta}{\beta}} \left(\frac{\tilde{A}_c}{\tilde{A}_p}\right)^{\frac{1-\alpha}{\alpha\beta}} \frac{L_c}{L_p} \frac{J}{1-J} \tag{A.32}$$

Substituting now for $\frac{\tilde{A}_c}{\tilde{A}_p}$ gives

$$\left(\frac{p(0)}{p(1)}\right)^{\frac{1}{\alpha(1+\beta)-1}} = \left(\frac{F_p}{F_c}\right)^{\frac{1-\alpha}{\alpha(1+\beta)-1}} \left(\frac{p_E}{\bar{R}}\right)^{\frac{\alpha(1-\beta)}{\alpha(1+\beta)-1}} \left(\frac{L_c}{L_p}\right)^{\frac{\alpha\beta}{\alpha(1+\beta)-1}} \frac{J}{1-J} \tag{A.33}$$

Since

$$\frac{p(0)}{p(1)} = \left(\frac{J}{1-J}\right)^{-\alpha} \tag{A.34}$$

$$\left(\frac{J}{1-J}\right) = \left(\frac{F_p}{F_c}\right)^{\frac{1-\alpha}{\alpha(2+\beta)-1}} \left(\frac{p_E}{\bar{R}}\right)^{\frac{\alpha(1-\beta)}{\alpha(2+\beta)-1}} \left(\frac{L_c}{L_p}\right)^{\frac{\alpha\beta}{\alpha(2+\beta)-1}} \tag{A.35}$$

such that

$$J = \left\{1 + \left(\frac{F_p}{F_c}\right)^{\frac{1-\alpha}{\alpha(2+\beta)-1}} \left(\frac{p_E}{\bar{R}}\right)^{\frac{\alpha(1-\beta)}{\alpha(2+\beta)-1}} \left(\frac{L_c}{L_p}\right)^{\frac{\alpha\beta}{\alpha(2+\beta)-1}} \right\}^{-1} \tag{A.36}$$

A.7 Prices for polluting and clean intermediates $p(0)$ and $p(1)$

As the price level of final output has been normalised to 1

$$\int_0^1 \ln p(i) di = 0 \tag{A.37}$$

Taking account for the comparative advantages of polluting and clean production technologies in producing intermediates $i \in [0, J]$ and $i \in [J, 1]$ allows us to separate the above equation into the following expression

$$\int_0^J \ln p(i) di + \int_J^1 \ln p(i) di = 0 \tag{A.38}$$

such that in light of (A.7) and (A.8)

$$\int_0^J \ln \left[p(0)(1-i)^{-\alpha}\right] di + \int_J^1 \ln \left[p(1)(i)^{-\alpha}\right] di = 0. \tag{A.39}$$

Noting that $\int \ln(x)dx = x \int \ln(x) - x$ and $\int \ln(1-x)dx = -(1-x)\ln(1-x) + (1-x)$

$$J\ln[p(0)] - \alpha \int_0^J \ln[1-i]di + (1-J)\ln p(1) - \alpha \int_J^1 \ln[p(i)]di = 0 \tag{A.40}$$

$$\rightarrow \quad J\ln[p(0)] - \alpha\Big[-(1-i)\ln[1-i] + (1-i)\Big]_0^J + (1-J)\ln p(1)$$
$$-\alpha\Big[i\ln[p(i)] - i\Big]_J^1 = 0 \tag{A.41}$$

$$\rightarrow \quad J\ln[p(0)] - \alpha\Big[-(1-J)\ln[1-J] + (1-J) - 1\Big] + (1-J)\ln p(1)$$
$$-\alpha\Big[-1 - J\ln[J] + J\Big] = 0 \tag{A.42}$$

$$\rightarrow \quad J\ln[p(0)] + \alpha(1-J)\ln[1-J] - \alpha(1-J) + \alpha + (1-J)\ln p(1)$$
$$+\alpha + \alpha J\ln[J] - \alpha J = 0 \tag{A.43}$$

$$\rightarrow \quad J\ln[p(0)] + \alpha(1-J)\ln[1-J] - \alpha(1-J) + \alpha + (1-J)\ln p(1)$$
$$+\alpha + \alpha J\ln[J] - \alpha J = 0 \tag{A.44}$$

Hence,

$$\ln[p(0)] = -\alpha\frac{1-J}{J}\ln[1-J] + \frac{J-1}{J}\ln[p(1)] - \alpha\ln[J] - \frac{\alpha}{J} \tag{A.45}$$

$$p(0) = [1-J]^{-\alpha\frac{1-J}{J}} J^{-\alpha} [p(1)]^{\frac{J-1}{J}} \exp\Big(-\frac{\alpha}{J}\Big). \tag{A.46}$$

In light of (A.34) we obtain further

$$p(0) = [1-J]^{-\alpha\frac{1-J}{J}} J^{-\alpha} \Big(\frac{J}{1-J}\Big)^{\alpha\frac{J-1}{J}} [p(0)]^{\frac{J-1}{J}} \exp\Big(-\frac{\alpha}{J}\Big) \tag{A.47}$$

such that

$$p(0) = J^{-\alpha}\exp(-\alpha) \tag{A.48}$$

and

$$p(1) = (1-J)^{-\alpha}\exp(-\alpha) \tag{A.49}$$