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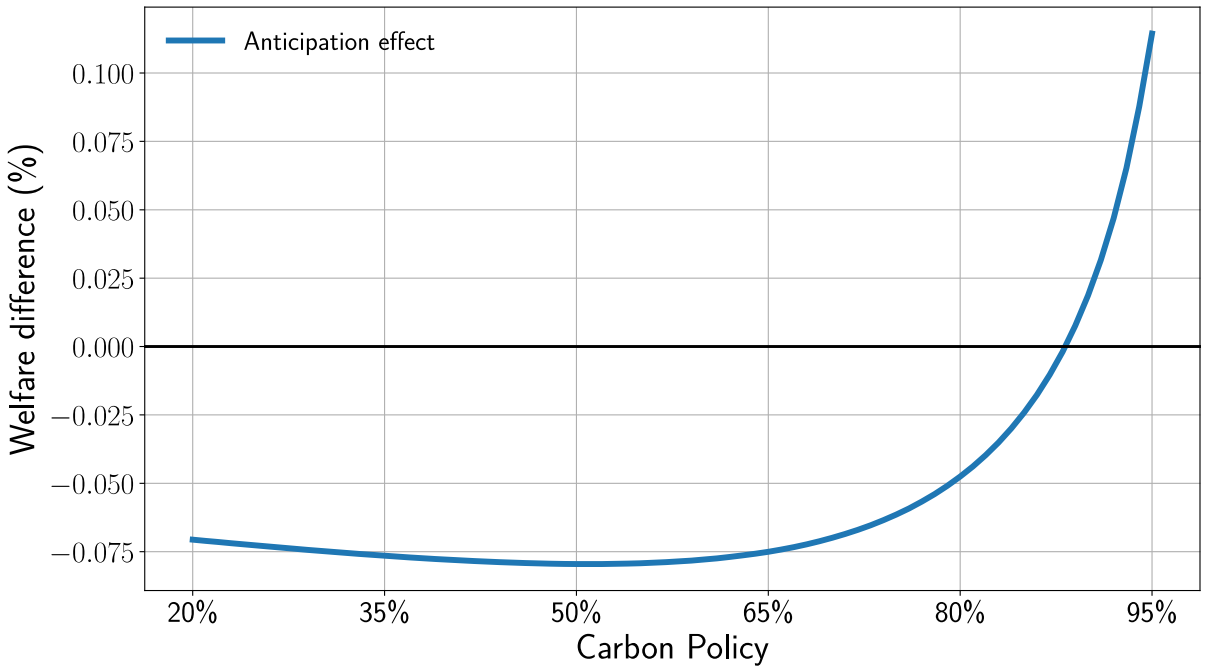
Expectation formation in energy markets and its impact on the success of future energy policies



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The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.

Zusammenfassung

Das Projekt untersucht die Hypothese, dass die aktuelle Forschung die historische Entwicklung der Ökonomie, Technologie und Energiesystemen zu stark gewichtet. Tatsächlich verwendet die gängige Literatur der Energie- und Makroökonomie hauptsächlich vergangenheitsbasierte Gleichgewichtsmodelle. Wir argumentieren hingegen, dass die Erwartungen bezüglich zukünftiger politischer Massnahmen einen bedeutenden Anteil am Erfolg der tatsächlich implementierten Energiepolitik haben.

Das Projekt zielt auf ein tieferes Verständnis des Erwartungsbildung-Prozesses ab im aktuellen Schweizer Energiekontext. Dazu erweitern und adaptieren wir die bestehende Theorie, sammeln relevante Daten und integrieren diese Informationen in einem quantitativen Modell. Das Projekt ist in 4 Teile gegliedert, welche die Rolle von Erwartungen in unterschiedlichen Kontexten analysieren. Im ersten Teil kombinierten wir theoretische und empirische Erkenntnisse über die Rolle von Erwartungen mit endogener Politikgestaltung. Im zweiten Projektteil analysieren wir die Ergebnisse von zwei Experimenten der Schweizerischen Haushalt- und Energiebedarfserhebung (SHEDS), bei denen wir die Manipulation von Erwartungen auf der Ebene der Einzelpersonen testen. In einem dritten Projektteil analysieren wir Erwartungen auf der Ebene einzelner Unternehmen und wie diese durch politische Signale beeinflusst werden können und integrieren diese Erkenntnisse in die Modellierung der Transition von einer fossilen zur grünen Produktionsweise. Im vierten Teil schliesslich integrieren wir die Rolle von Antizipationseffekten durch Ankündigungen in das CITE-Modell, um die direkten Auswirkungen energiepolitischer Massnahmen auf die Schweizer Wirtschaft zu untersuchen.

Die Ergebnisse aus den vier Teilprojekten unterstreichen die Bedeutung von Erwartungshaltungen. Sowohl für die Modellierung als auch die ökonomische Forschung generell sollte die Rolle von Erwartungen mehr einbezogen werden. Erstens spielen Erwartungen eine zentrale Rolle bei der Wahl des langfristigen Wachstumspfads. Zweitens können glaubwürdige Signale die Erwartungen beeinflussen und dabei helfen, Investitionsentscheide anzupassen und Unsicherheiten zu reduzieren.

Résumé

Le projet étudie l'hypothèse selon laquelle la recherche actuelle surpondère le développement historique de l'économie, de la technologie et des systèmes énergétiques. En effet, la littérature actuelle sur l'énergie et la macroéconomie utilise principalement des modèles d'équilibre basés sur le passé. Nous soutenons cependant que l'anticipation de politiques futures a une part importante dans le succès des politiques énergétiques mises en œuvre.

Le projet vise à mieux comprendre le processus de formation de ces anticipations économiques dans le contexte énergétique suisse actuel. Pour ce faire, nous contribuons à la théorie existante, et nous l'enrichissons à l'aide des données que nous intégrons dans un modèle quantitatif. Le projet est divisé en quatre parties, qui analysent le rôle des anticipations économiques sous différents angles. Dans la première partie, nous combinons des résultats théoriques et empiriques sur le rôle des anticipations économiques avec un modèle dans lequel l'élaboration de politiques environnementales se fait de manière endogène. Dans la deuxième partie du projet, nous analysons les résultats de deux expériences de l'enquête

suisse sur les ménages et la demande d'énergie (SHEDS). Ces données nous permettent de tester la formation des anticipations économiques au niveau des individus. Dans une troisième partie du projet, nous analysons les anticipations économiques au niveau des entreprises et la manière dont ces anticipations peuvent être influencées par des signaux politiques. Pour compléter ces résultats empiriques au niveau des entreprises, nous les intégrons dans un exercice de modélisation de la transition écologique. Enfin, dans la quatrième partie, nous nous intéressons au rôle de l'annonce d'une politique environnementales sur les anticipations économiques par dans le modèle CITE afin d'examiner l'impact des politiques énergétiques sur l'économie suisse sous un angle nouveau.

Les résultats des quatre sous-projets soulignent l'importance des anticipations économiques qui, tant au niveau la modélisation que pour la recherche économique au sens large, se doivent d'être davantage prisent en compte. Non seulement parce qu'elles jouent un rôle central dans le choix de la trajectoire de croissance à long terme, mais également du fait qu'elles peuvent être influencées par des signaux politiques crédibles, ce qui peut aider à ajuster les décisions d'investissement et à réduire les incertitudes économiques.

Summary

The project builds on the hypothesis that current research and policy debates put a too strong emphasis on the historic evolution of economy, technology, and energy systems. As a matter of fact, most of the literature in energy and macroeconomics deals with purely history-dependent equilibria. We argue that the formation of expectations and the coordination of expectations by appropriate policies are crucial for the success of future energy policies.

The project aims at a thorough understanding of the detailed process of expectation formation in the current Swiss energy context. To provide answers we expand and adapt the theory, gather relevant data (existing and additional) and integrate the information into a quantitative setup. The project is structured in 4 sub-projects which analyze the role of expectations in different settings. In the first sub-project we combine theory and empirical findings on the role of expectations with endogenous policy-making. In the second sub-project we analyze the results from two experiments in the Swiss Household and Energy Demand Survey (SHEDS) where we test expectations on the level of individuals. In the third sub-project we analyze expectations on the firm-level and how governmental signals can shape these and we use these insights for modelling the transition from dirty to green production. Finally, in the fourth sub-project, we integrate the role of expectations in the CITE model in order to study the effects of the direct implementation of energy policies on the Swiss economy.

The findings from this research project underline the importance of expectations and the respective need to take them into account in modelling and economic research overall. First, expectations play a crucial role in determining the development path of an economy. Second, credible signaling in order to shape expectations can then help to align investments and reduce uncertainties.

Main findings

Our project reveals that expectations are of high relevance for economic actors, and policymakers.

First, expectations about the general development influence the growth path of an economy. Thus, they should be taken into account in growth projections and respective cost estimations of policies.

Second, individuals adjust their investment decisions if they expect a changing policy framework. Early, credible announcements about policies can thus help to align investments on the consumer level.

Third, for entrepreneurs, early knowledge about future policies seems to influence the assessment of a business case and the decision to enter a market. Hence, credible signaling has the potential to influence the speed of the energy transition.

Finally, the numerical analysis tailored to Switzerland confirms that the anticipated policy can bring the economy to a different equilibrium in comparison to its unanticipated analogue. The results underscore the importance of considering the broad set of economic forces and incentives triggered by the anticipation of a policy.

Contents

Abbreviations

BAU	Business-as-usual
BGP	Balanced growth path
CGE	Computable General Equilibrium
DGE	Dynamic General Equilibrium
EIV	Einmalvergütung
IOT	Input-Output Table
KEV	Kostendeckende Einspeisevergütung
SHAB	Schweizerisches Handelsamtblatt
SHEDS	Swiss Household and Energy Demand Survey
ZEV	Zusammenschluss zum Eigenverbrauch

1 Introduction

1.1 Background

Current research and policy debates put a strong emphasis on the historic evolution of economy, technology, and energy systems. Most of the literature in energy and macroeconomics deals with purely history-dependent equilibria: given the initial conditions (e.g., for capital and knowledge stocks), market participants optimize over a certain time horizon determining unique paths for future consumption, energy use, and investments.

A policy can modify the market equilibrium by changing restrictions and relative prices, but, currently, there is no specific role for expectations. We argue that the formation of expectations and the coordination of expectations by appropriate policies are crucial for the success of future energy policies. If expectations for a regime switch are favorable, we expect positive momentum effects and speeding moments reducing the costs of energy policy substantially. In this project, we thus seek to shed light on the question, whether and how appropriate policy can help to avoid unfavorable income effects during the energy transition.

1.2 Role of expectations

Most economic theory models the growth path of economic development based on past development (i.e., Acemoglu et al., 2012). If past development ("history") determines the transition to long-run equilibrium, a shift to a new steady-state requires significant and potentially expensive policy interventions, which might be hard to get approved by the political process. Because learning effects are sector-specific, history favors the larger sector which is usually the dirty sector of the economy. To change the pattern of development, a policy is needed to give the green sector the decisive initial push.

However, if the equilibrium is also determined by "expectations" of cleaner future production, the policy has only to be active in an initial phase. After that, induced investments may create major network, momentum, and scale effects. Hence, expectation-driven equilibria can support initial policy and lower the costs of the transformation of energy systems significantly.

Starting with the seminal paper of Krugman (1991) there are a few contributions, which distinguish between history and expectations as the determinants of an equilibrium selection process. Schaefer et al. (2014) build on Krugman (1991) and consider a general equilibrium allowing for capital and labor mobility but neglecting factor accumulation. Bretschger and Schaefer (2017) introduce these aspects into a dynamic general equilibrium model where the relevance of expectations can be altered by energy policies. Van der Meijden and Smulders (2014) extend the approach of Acemoglu et al. (2012) by introducing expectations in a directed technical change framework, but they assume that changes in expectations stem from new outside information.

Although Bretschger and Schaefer (2017) show how taxes on polluting fossils and/or subsidies to non-polluting renewable energy services affect the interplay between history and expectations, they consider highly stylized policy instruments. It thus lacks a clear and detailed analysis of more realistic policy instruments and combinations of them with their impact on the relevance of expectations and the macroeconomic performance in the short and

the long run. Like the existing literature, it also abstracts from mechanisms that influence the coordination of expectations on the macro-level of an economy.

In addition to the positive momentum effects of expectations, it is also important to note the potential costs in case of wrong expectations and uncertainties about the future. In particular, there can be high costs related to so-called stranded assets—that is, assets that prematurely or unexpectedly decrease in value due to physical shocks or societal responses to climate change, such as the policy framework (Caldecott, 2017). Large investments can create lock-in effects (Seto et al., 2016) and, if a locked-in investment becomes stranded, a necessary policy change becomes very costly and unattractive.

Long-term policy targets help industries to plan ahead and thus reduce the risk of stranded assets. For the coordination of such expectations, there is substantial research in other fields. In particular, in monetary policy research the use of information has become an extensively analyzed policy instrument (e.g., Bernanke, 2004, Romer and Romer, 2000). Finally, some research focuses on the role of long-term policy targets to align firms' innovation activities (Schmidt et al., 2017).

Surprisingly, there is currently no research on the role of expectations regarding future policies at the household level. Purchases of durable consumer goods depict a substantial investment for households. Policies that devalue such investments can significantly impact households. At the same time, decision and implementation of stringent policies largely depends on the support within the population (e.g. Steg and Schuitema, 2007). Scholars have shown, that expected costs for yourself and others determine whether a policy is perceived as fair (e.g., Ziegler, 2019, Huber et al, 2019). Thus, a better understanding of the potential costs and losses due to wrong expectations on the household side is crucial for the definition of adequate policies to achieve the energy transition.

For both, expectations of investors at the institutional level and individuals, the credibility of any signals is key. Time inconsistency is a common issue when optimal policies ex-ante differ from the optimal ex-post (e.g., Alesina and Tabellini, 1988 and Helm et al., 2003).

1.3 Purpose of the project

This research project aims at bridging the gap between policies that serve as credible signals for investors and the coordination of their expectations.

The project builds on the theoretical foundation of Bretschger and Schaefer (2017), which develops a multiple steady-state framework with economic policy affecting the relevance of expectations against history for the equilibrium selection process. While the paper provides a general analytic foundation, this project aims at a more extensive understanding of the detailed process and effects of expectation formation in the current Swiss energy context. Moreover, we seek to derive how specific policies affect the coordination of expectation in a market and thus the interplay between history and expectations.

The project aims to answer the following research questions:

1) How do realistic energy policies affect the interplay between history and expectations?

2) What are the differences between taxes and subsidies in this context?

3) How can the government coordinate expectations?

4) How do the costs of energy policies change with expectations?

5) What are the specific issues and results for the Swiss economy and policy?

To answer these questions, we expand and adapt the theory, gather relevant data (existing and additional), and integrate the information into a quantitative setup.

2 Project Overview

We split the research project into 4 sub-projects, each addressing one or two of the research questions with different methods and perspectives.

Project 1 (P1): Macro perspective: How do green preferences affect economic performance and a regime switch if expectations and history matter?

- DGE model where history and expectations matter with endogenous policy-making based on green preferences of households.
- Empirical analysis: the relationship between economic optimism and green preferences; Data from Selects, Switzerland.
- Addressing research questions 1 and 4.

Project 2 (P2): Household perspective: How does consumer behavior change if expectations matter?

- In macroeconomic models, agents' expectations influence the capital accumulation of firms. Agents are also investors as consumers and choose between different durable consumer goods. The announcement of a policy alters their choice.
- Experiment: analysis of behavior changes in light of early policy information; Data from the Swiss Household Energy Demand Survey (SHEDS).
- Addressing research questions 3 and 4.

Project 3 (P3): Policy announcements and economic activity: modeling the energy transition on the micro-level

- The existing papers and attempts model a switch from a dirty to a green regime. Now: 1) model a transition where both sectors (green and dirty) can be active. 2) analyze the credibility of signals from the government to coordinate transition via expectations.
- Theory: DGE model with an analysis of optimal governmental behavior (signaling) in a two-period setting.
- Empirical analysis: impact of government signaling (future policies) on the number of firm entries; Data from the Swiss Commercial Registry (SHAB).
- Addressing research questions 1 and 3.

Project 4 (P4): Integrating previous insights into the Computable Induced Technical change and Energy (CITE) model

- Implementing the concept of expectations of a policy prior to its implementation in a dynamic CGE model for Switzerland.
- Calibration of the model to the latest available data for Swiss economic sectors and households.

- Studying the impacts of the expectations of policies of increasing stringency on the Swiss economy.
- Addressing research questions 2, 4 and 5.

Overall, we define 4 milestones:

(1) Development of a holistic theoretical model framing the role for expectations in a dynamic macroeconomic context.
(2) Implementation of a government into the set-up developed in 1) which is able to align and coordinate expectations.
(3) Empirical research on the impact of expectations and attitudes on consumer and firm behavior.
(4) Implementation of results into a large-scale dynamic computable general equilibrium model calibrated for the Swiss economy with the aim to simulate policy experiments.

Projects 1 and 3 address milestone 1, project 3 addresses milestone 2, projects 1, 2, 3 address milestone 3, and finally, project 4 addresses milestone 4.

3 Project 1: How do green preferences affect the economic performance and a regime switch if expectations and history matter?

In P1 we analyze the impact of endogenous environmental policies on the relevance of history and expectations for the equilibrium growth process. We discuss the steady-state dynamics of a DGE model in light of empirical findings on economic expectations and green preferences. The original paper is published as "The impact of green preferences on the relevance of history versus expectations" in *Environment and Development Economics*, 2019. A post-refereeing version of the article can be found in chapter 2 of *Governing climate change and humanitarian migration: the role of expectations and equity*, Doctoral Dissertation Anna Stünzi, ETH Zurich, 2020, which is available open access.

With an overlapping generation (OLG) model it is shown that in a polluting regime environmental preferences cause an increasing energy tax. This raises the risk that the economy transitions to the inferior equilibrium under pessimistic expectations. At the same time, however, higher environmental preferences imply an earlier switch to the clean energy regime. Then, the conflict between marginal costs for production and environmental preferences is resolved and the prospects of selecting the superior equilibrium improve, since positive expectations become more relevant.

Using a panel dataset from Switzerland we find that people with strong environmental preferences tend to also have more optimistic expectations about economic development. Thus, we refute widespread beliefs that people have to decide between stringent environmental-protection policy measures or economic growth. A majority of surveys are designed in a way that participants have to set their preference on a scale where promoting economic growth and policies for environmental protection are mutually exclusive. With our analysis, we can show that individuals would not make this strict bifurcation. Instead,

participants that were in favor of environmental policies were also more likely to be optimistic with respect to economic growth.

Using these empirical findings to analyze the steady-state dynamics implies that agents with environmental preferences support higher energy taxes and switch to clean production more quickly. Due to their optimism, the likelihood of reaching the superior stable steady-state increases. In other words: we argue that in a society where individuals push for more stringent environmental policies, economic growth can still boost when (and because) the expectations about the development of the economy are optimistic.

4 Project 2: How does consumer behavior change if expectations matter?

In P2 we extend the analysis on the role of expectations to the household level. An experiment implemented in the Swiss Household and Energy Demand Survey (SHEDS) 2018 allows us to analyze indicated behavioral change in light of changing expectations about a future policy framework.

In the experiment, we give a sample of participants additional information about future policies that either maybe or definitely are going to restrict the usage of vehicles with an internal combustion engine. Having this additional information induces participants to be more likely to actually choose an electric vehicle, even if they have not intended to do so beforehand. This indicates that participants integrated new information on future policy information and adjusted an investment decision potentially affected by the policy. In the paper, it is proposed that the ability to adjust may also increase acceptance and support for the policy, an interesting path for future research. The experiment and results are explained and discussed in detail in chapter 3 of *Governing climate change and humanitarian migration: the role of expectations and equity*, Doctoral Dissertation Anna Stünzi, ETH Zurich, 2020, which is available open access.

The same data and experiment are also used to analyze the availability to try Mobility-as-a-Service solutions. Again, after receiving information about future policies that might restrict the usage of a fossil-powered vehicle, participants were more likely to be open for trying such new mobility services. The original paper is published as "What are the factors and needs promoting mobility-as-a-service? Findings from the Swiss Household Energy Demand Survey (SHEDS)" in *European Transport Research Review*, 2020, which is available open access.

Finally, in SHEDS 2019, a similar experiment was set up in the area of housing and buildings. The aim was to test whether information about the policy framework with regards to replacement of heating systems and insulation of buildings would incentivize households for an earlier renovation. A very large majority of the sample indicated, however, that they would support a renovation very soon anyway, independent of the future policy framework. In particular, more than 90% of the tenants said that they would accept a renovation in the near future. More than 50% of the tenants also said that they would accept rent increases exceeding the provisional 40 CHF savings in energy bills every month. While the results are interesting and will be discussed in an additional paper, they were not analyzed further within the frame

of this research project. Still, an analysis and discussion of the preliminary results were published on the *ETH Energy Blog* in 2019.

In summary, the empirical findings suggest that individuals actively take into account future limitations of policies. They are likely to adjust investment decisions and try new mobility services in order to adapt to a new policy framework.

5 Project 3: Policy announcements and economic activity: modelling the energy transition on the micro-level

5.1 Introduction

In this project, we analyze the transition from a fossil (dirty) to a green (clean) regime based on the firms' decision to adopt green technologies. The research question is based on the premise that firms newly enter the market and/or adopt new technologies if they expect positive revenues in the future compared to entering any other (i.e. dirty) or no market. Related to the entry decisions of green or dirty energy service providers, we then analyze how expectations can be shaped via credible signaling of the government. The work is still preliminary, but we summarize the current state of research in the following.

As outlined in the introduction, there is surprisingly little research on the announcement effects of policymakers. Existing economic literature describes entry and exit decisions of companies mostly in light of the product lifecycle theory, innovation and technological advances (e.g. Geroski, 1995), market saturation (e.g. Agarwal and Gort, 1996, Campbell, 1997) and entry costs (e.g. Shapiro and Khemani, 1987). Furthermore, there are empirical analyses, examining attributes that incentivize market entries in retail (e.g., Carree and Thurik, 1996), with respect to new business areas (e.g., Chang, 1996) or export markets (e.g., Bernard and Wagner, 2001). Political science literature has analyzed the interplay between technological change and policymaking in light of the energy transition (e.g., Schmidt and Sewerin, 2017, Hoppmann et al., 2014). However, these papers analyze the total deployed capacity and not the economic activity on the firm-level. As Shen (2014) shows, firms are more likely to enter a market in the prospect of demand taking off soon. Policy measures such as subsidies aim to increase demand and should therefore positively influence the expectations of entrepreneurs. With regards to the relationship of market entries and policy announcements, we could not find any theoretical nor empirical work.

With this project, we aim to address this gap in current research. In a first step, we analyze empirically whether the announcement effects of policymakers in the context of the energy transition affect current economic activity. To do so we propose the analysis of data that has - to our best knowledge - so far not been used for any empirical analysis. We look at the impact of specific policy announcements fostering the energy transition on the number of firm entries in Switzerland. We identify key decisions in the Swiss parliament with respect to the support of green energy use and test whether the bare number of firm registration changes following

these major decisions. Our study reveals a significant relationship between information on future policies and firm entries.

Based on these findings, the ignorance of potential announcement effects is not reasonable. In contrast, they seem to be crucial for the formation of entrepreneurs' expectations about the evolution of the future policy path. We use this result as the entry point for our theoretical model. Similar to the framework from monetary policy research that studies inflation expectations, a policymaker has to be able to commit credibly to an announced policy. The discussion about the relevance of announcements thus involves the dimensions of credibility and time-consistency.

5.2 Methodology and Data

Similar to P1 we combine macroeconomic theory with an econometric analysis.

For the econometric analysis, we look at data from the Swiss Commercial Registry (SHAB). We use web-scraping techniques to collect data from the SHAB archive and combine it with research on decision-making and implementation of political measures regarding renewable energy use. We investigate the number of newly founded companies (thus entrepreneurs with positive expectations) for the time before the decision-making, and signal of the government, after the signal and after the implementation.

For the firm entries, we define three keywords "Solarenergie", "Erneuerbare Energie*" and "Solaranlage*". At least one of these entries has to be present in the purpose of the newly registered firm. As such we make sure that the company's operation is related to green energy. In total there are 828 newly registered firms between 1.1.2002 and 31.08.2018.

For determining the signals, we manually draw a timeline of political decisions with respect to energy policy in Switzerland for announcements (date of decision) and implementation date. The analyzed policies were planned to increase the share of renewable energy consumption by reducing the upfront investment cost ('EIV'), increasing the revenues for selling the electricity to the local energy providers ('KEV'), the reduction of planning requirements ('plan') and increasing transparency about the electricity mix that is supplied ('trans).

In addition, we use data about the annual PV module prices (Fraunhofer ISE, 2017 and IRENA, 2019) and the general business environment (i.e. annual registries of new firms in Switzerland) (SHAB, 2020) as control variables.

Finally, we compare the solar industry with another specific industry in Switzerland, the phone industry. The aim of this comparison is to make sure that the specific date of the announced policies can be more easily interpreted as the reason for the increased registries and not due to any other event that would influence the sector. Since the solar industry is dependent on imports of products (in particular from Asia) our aim was to find an industry that similarly depends heavily on imports and has a roughly similar size. During the same time period, there are 1984 newly registered companies related to phones and mobile communication.

For the theoretical part, we build on seminal contributions to the literature on appropriate technologies (e.g. Atkinson and Stiglitz, 1969; Acemoglu and Zilibotti, 2001) to allow for the coexistence of green and polluting technologies. Higher market entry of green energy

providers increases the share of adopted green technologies in the economy. We then analyze different government strategies in a two-period setting, where weak and strong governments announce a future policy.

The starting point of our reasoning is that policy announcements and in particular their credibility matters regarding their impact on economic activity. The credibility of policy announcements is intimately linked to the notion of time-inconsistent behavior of governments, in the sense that they might not have an incentive to stick to their initial announcements after agents have acted accordingly. Rational agents, however, know that the government may have an incentive to deviate from its announcement and they will consequently not engage in actions matching the government's initial announcements. For instance, the government could announce a subsidy, entrepreneurs invest, and the government has no incentive to implement the subsidy anymore. Rational agents expecting such a deviation would never invest from the outset. This mechanism survives repeated interactions as any punishment from such deviation can only materialize in the future and its assessment therefore depends on the government's time preference rate.

As it has been stated earlier, it is somewhat surprising that these mechanisms haven't been analyzed in the context of energy policies. The credibility of policy announcements, however, has a long tradition in theoretical contributions around monetary-policy issues, specifically in the literature dealing with the so-called inflation bias. As a first step, our theoretical model makes thus use of these theories in order to shed light onto mechanisms that may support the credibility of policy announcements in the context of the energy transition. Conceptually, we build on the inflation-bias literature (Barro and Gordon, 1983 and Cukierman and Liviatan, 1991) as well as on the literature about weak institutions (Acemoglu, 2006).

5.3 Results

Empirical analysis

The results are still preliminary. Nevertheless, we describe the current state of the analysis and shortly discuss our observations.

Figure 1 shows the development of firm entries divided into the different policy announcement and enactment periods. Overall, the curve shows an increase until mid-2012 and then a rapid decrease with a more unstable course within the latter years. The course of the curve is similar to the development of jobs in the solar energy industry in Switzerland (i.e. Swissinfo, 2017).

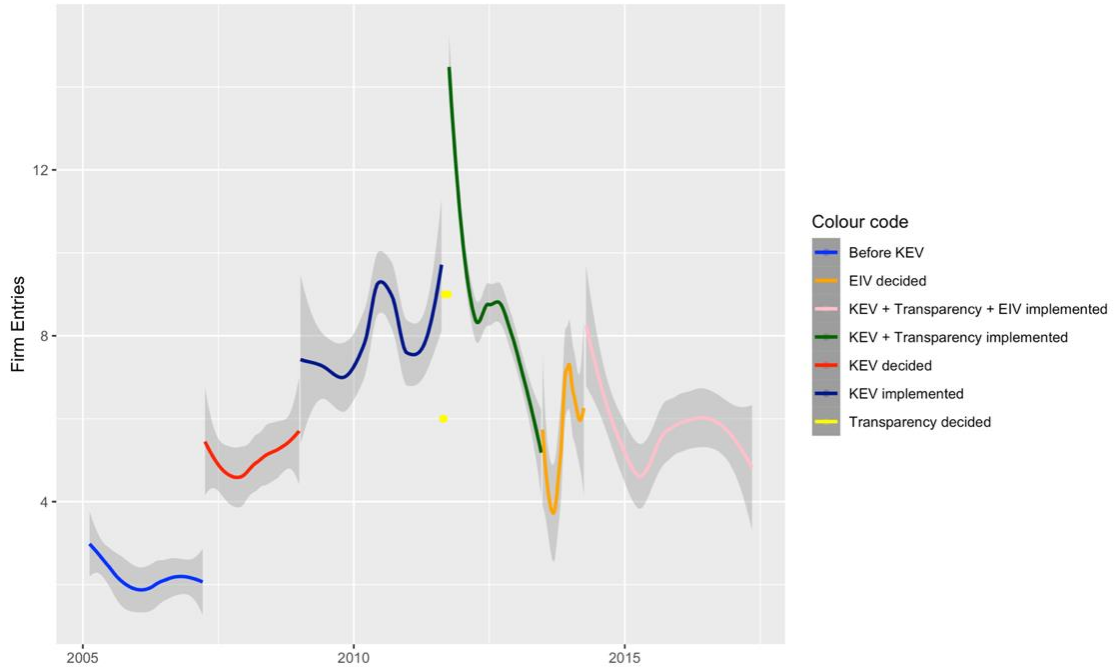

Figure 1: Number of firm entries before/after political decision-making / implementation of policies in the renewable energy sector.

Figure 1 suggests that there is a significant increase in the number of firm registries after the parliamentary decision to introduce the KEV in 2007 - already before the policy was enacted (1.1.2009). The level of firm entries remains constantly higher after the decision of the KEV introduction.

Using OLS regression we then analyse the impact of the announcements and enactments of each policy on the number of firm entries. As table 1 shows, the coefficients for the KEV and EIV announcements are highly significant and also stable if we control for seasonal variation, prices for PV panels, and the general business environment. We don't see the same effect of the policy announcement in the phone industry, indicating that the announcements were indeed important for the solar industry only.[1]

The coefficients of the announcements for the transparency and planning regulations are not significant. There was nearly a two-year timespan between the decision and implementation of the KEV and more than a year for the EIV. The other policy measures were decided and implemented in a much shorter timeframe. This would explain why the announcements are not significant, but only the implementation. Put the other way, if the policies were announced earlier, a positive impact could potentially have been observed thanks to respective expectations.

As we can see for the EIV coefficient, the announcement can also induce negative expectations. The large underfunding of the KEV (and related to that a lot of projects waiting for approval and finance) was one of the main reasons for implementing the EIV, which is a much smaller subsidy. This could be a reason for the negative coefficient after the parliamentary decision to

[1] The highly significant impact of the planning decision on the phone industry is most likely determined by another decision in the parliament and will have to be investigated further.

implement the EIV: expectations about reduced future subsidies decreased the attractiveness of entering the market.

Model

Our stylized model comprises two periods and two types of governments, a strong type being able to commit credibly to environmental policies and a weak type which is unable to commit. As the public is unable to observe the type of government, firms form believes about the type of government being in place.

From the perspective of a weak government it is now rational to mimic the announcement of a strong government in the first place, but then to reveal its identity when it comes to the implementation of the policy (separating equilibrium). On the other hand, any weak government may mimic the strong government in the first period completely, i.e. not only mimic the strong government's announcement but also its policy.

Realistically the timeline of events is as follows: The government announces a pollution tax which is a metaphor for any other environmental policy. Firms form expectations about the tax rate based on their beliefs that the government in place is strong or weak. Based on this expected tax rate firms invest in a productivity level or switch to a non-pollution technology. Finally, firms produce, and the tax rate is implemented. A strong government appreciates the trade-off between a high level of output and environmental depreciation, while a weak government ignores the environment completely, i.e. it prefers a tax rate of zero.

	Dependent variable:	
	Count	
	(solar)	(phone)
kev1	4.160^{***}	-0.657
	(0.620)	(0.475)
kev2	7.939^{***}	1.630^{*}
	(0.979)	(0.824)
eiv1	-4.550^{***}	1.114
	(0.634)	(0.611)
eiv2	-7.600^{***}	2.280
	(1.043)	(1.258)
plan1	-0.405	4.162^{***}
	(1.072)	(0.920)
plan2	4.465^{***}	-2.214
	(1.007)	(1.215)
trans1	1.091	-2.384^{*}
	(0.695)	(1.154)
trans2	1.957^{***}	-0.628
	(0.324)	(0.363)
seasonal variation	✓	✓
New.companies	✓	✓
PV price	✓	✓
Constant	-0.800	6.077^{***}
	(1.753)	(1.579)
Observations	828	1,984
R^2	0.513	0.478
Adjusted R^2	0.500	0.472
Residual Std. Error	2.263 (df = 806)	3.162 (df = 1962)
F Statistic	40.406^{***} (df = 21; 806)	85.477^{***} (df = 21; 1962)
Note:		*p<0.05; **p<0.01; ***p<0.001

Table 1: OLS regression analysis. Comparison between solar and phone industry.

Our model suggests that a weak government has no incentives to mimic the strong government (pooling equilibrium) since this reduces its payoff below the one obtained from revealing its identity in the first period already (separating equilibrium). This implies that agents have very early clarity about the identity of the government in the sense that agents are not surprised about the true identity of the government after a policy has been implemented. Weak governments would announce a strong government's policy but never implement it and surprise the audience by changing their minds.

5.4 Conclusions

Most economic research simplifies the energy transition to a switch from dirty to clean technology. With this project we make a first approach to analyze a real transition, where entrepreneurs and firms decide over time to newly enter a market or change the production technology. In addition, we allow the government to actively shape expectations via signals

on future policies and thereby influencing the transition. This represents an energy transition challenge that is much closer to the real-world challenge.

The empirical analysis suggests that early (positive) policy signals help to align expectations and induce entrepreneurs to enter a new market. The theoretical model then explains why an announcement of a government can be effective to shape expectations. Announcements are likely to be credible when the audience realizes that governments in place do not have an incentive to just mimic environmental policies. This is in particular then the case when the economy adjusts in response to these policies. In this case s switch to the former status quo might difficult.

6 Project 4: CITE model: Role of policy anticipation in the Swiss economy

6.1 Introduction

As global CO_2 emissions keep rising, economic instruments that aim at reducing fossil fuel use may have to reach high stringency levels. The literature extensively examines the effects of the implementation of such policies on economic sectors, households, and the aggregate economic growth. The effects that the policies might trigger before their factual implementation, however, have not received enough attention. Despite the common notion that the knowledge about and the preparation to an upcoming carbon policy might give rise to an entirely different equilibrium path, particular implications for an economy in general equilibrium context stay unclear. We address this question by highlighting the economic and welfare implications of the expectation of a carbon tax policy in a numerical general equilibrium model of a multi-sectoral economy with endogenous growth and heterogeneous households with labor-leisure choice.

In the field of environmental economics, most of the conventional studies consider the effect of the announcement of a policy through the prism of the green paradox (Sinn, 2008). The concept of green paradox applies when climate regulations have an effect that contradicts the intended one—for example, by inducing earlier or more intensive extraction of fossil fuels rather than their conservation. Such adverse effects may arise if the policy is anticipated in advance and also if it has a steep profile (Jensen et al., 2015). The presence and strength of the green paradox effect are conditioned on many factors including the extraction and adjustments costs for fossil energy and the availability of clean substitutes (van der Ploeg and Withagen, 2015). Yet, the scarcity of fossil fuels is not a necessary component as the unintended consequences may arise purely from the adjustments in consumption-investment decisions in anticipation of a policy that would make fossil energy more expensive in the future (Smulders et al., 2012).

As summarized in the introduction and proposed by P1, the literature that juxtaposes "history" with expectations suggests that it is not only the current, realized state of economy, but also the expectations about the future states that determine its equilibrium path. In our analysis, the effect of the expectation of a policy is isolated by comparing analogous carbon tax policies that differ only in the time of announcement. In the "anticipated" case, a policy is announced one period in advance such that the agents can adjust before the actual

implementation of a policy. In the "unanticipated" case, a policy is implemented right away without prior announcement, and the agents have to adjust their choices subject to a carbon tax. Given that the policy target (that is, the carbon budget) is the same in the two cases, the differences in the equilibrium paths that the economy follows result purely from the presence of the advance anticipation of a policy.

To study the effect of anticipation, we use the CITE model of computable general equilibrium with endogenous growth (Bretschger et al., 2011). We calibrate the model to the Swiss economy with its major sectors and five household groups of different income and working status and study the repercussions of the anticipation period at various stringency levels of carbon tax.

We find that the presence of the adjustment period drives the economy to a different equilibrium in terms of the allocation of resources, sectoral and aggregate growth, household choices for labor supply, and the growth rates of consumption. Moreover, the effects of anticipation are qualitatively different for mild and strict policies—even though we find no direct evidence of the green paradox. The announcement of a carbon tax triggers changes in consumption-investments decisions as agents prepare to the expected imposition of the tax. At the same time, knowing about the future policy, they start shifting their consumption towards the non-polluting energy already in the anticipation period. Since the agents foresee a decrease in the future aggregate output and consumption due to the tax, they face the trade-off between consumption smoothing in the short run and investing in the long-run. The households' ability to shift the consumption is determined by the structure of their incomes and the market conditions that they face, whereas the opportunity to gain from investment reallocation depends on the share of capital they own. The way this trade-off is resolved essentially defines the sign and magnitude of the anticipation effect on the aggregate welfare.

6.2 Methodology and Data

In this Section, we describe the economic data we use and the model that we calibrate to these data. We also explain our computational strategy for solving the model.

6.2.1 Households and sectors data

We use the Swiss Input-Output Table (IOT), Energy Input-Output Table (EIOT, Nathani et al., 2019) as well as the Household Budget Survey data (HABE) of the year 2014 (they are the latest data available) to construct the Social Accounting Matrix (SAM) of Switzerland.[2] In Table 2 we detail the aggregation of the 77 economic sectors of the IOT into the 11 sectors we use in the study. The energy sector is further desegregated into fossil (oil, gas, heat) and electricity sources following Bretschger et al. (2011). Because the electricity sector in Switzerland emits hardly any CO_2, we consider it as a clean energy technology and alternative to fossil fuels.

The HABE data contains information on 9'367 Swiss households that we summarize in Table 3. We aggregate these households into five categories based on their working status (active or retired) and level of net income (low, medium or high for active households and low or high for retired households). After aggregating the households and taking into account the number of people living in each household, we find that about 80% of the population is active, among

[2] The data are provided by the Federal Statistical Office of Switzerland.

which 44% is in the active-low group. The active-high and the retired income groups own most of the capital of the economy (62%) but the active high receives about two times as much income from labor as from capital, whereas the two retired income groups rely almost entirely on their capital earnings. The numbers are comparable to those in Karydas and Zhang (2019), where heterogeneous groups were incorporated in CITE based on the Swiss IOT and HABE of the year 2008. Note that we calibrate the model considering the pre-existing taxes and subsidies of the Swiss economy in the benchmark calibration.

Sector label	*Description*	*NOGA Divisions*
AGR	Agriculture	01-03
CHM	Chemical Industry	20-21
MCH	Machinery and Equipment	26-30, 33
EGY	Energy (Electricity, Oil, Gas, Heat)	19, 35, 38
CON	Construction	41-43
TRN	Transportation	49-52
BNK	Banking and Financial Services	64
INS	Insurances	65
HEA	Health	86
OSE	Other Services	36-39, 45-47, 53-63, 68-97
OIN	Other Industries	05-18, 22-25, 31-32

Table 2: Mapping of NOGA divisions to sectors

Category	*Source*
Income	Labor, Capital, Transfers
Spending	Consumption, Investments
Taxes	Income, Labor, Subsidies, Tariffs
Activity status	Active or Retired
Size	Number of people living in each household

Table 3: Description of the data on the 9'367 Swiss households

6.2.2 Economic Model

We use the CITE economic model of general equilibrium with endogenous growth developed by Bretschger et al. (2011). The growth mechanism in CITE is an extension of the increasing-variety model of Romer (1990) and includes energy use in the production of the intermediate good. This extension makes it possible to examine how the substitutability between labor and energy might affect economic growth when their relative prices change under various policies or other changes in economic conditions. CITE models a small open economy that consists of different regular, non-energy sectors of an economy and four energy-specific sectors—oil, gas, heat and electricity. All sectors have similar structures of production that feature three levels: the production of the intermediate goods, the production of sector-specific intermediate composite, and that of the final good. We assume that knowledge is sector-specific and we do not consider international knowledge spill-overs. Below we outline the main features of the model.

Production

For each sector i, the markets for final good (Y_i), intermediate composite good (Q_i), and labor (L_{X_i} and L_{J_i}) are perfectly competitive. Firms, however, can invest in physical (I_{P_i}) and non-physical (I_{N_i}) capital to invent new varieties of goods and enjoy profits from their monopolistic position. This constitutes the capital (J_i) of the sector. The nesting of the model is such that the fossils are combined with electricity first to produce the energy aggregate. The latter is then nested with labor to produce intermediate goods x_i. The amount of accumulated capital (J_i) determines the number of varieties that comprise the intermediate composite Q_i. The formulation can thus be classified as K-LE form of nesting in the production function.[3] Figure 2 provides an overview of the production structure for each sector of the economy.

At any time t, the labor employed in research, L_{J_i}, and labor employed in the production of the intermediate goods, L_{X_i}, face the same wage w_t determined on the competitive market.

Consumption and welfare

We follow Karydas and Zhang (2019) and define five categories of households based on their income levels and activity status as mentioned in Section 6.2.1. All households maximize their utility from consumption and leisure. We proxy leisure with the labor force participation rate, taking the calibration from Karydas and Zhang (2019).[4] Figure 3 sketches consumption and welfare choices in the economy.

The agents have perfect foresight, they allocate their income between consumption and investment, all markets clear, and the allocation and price vectors constitute a competitive equilibrium.

International trade

As CITE models a small open economy, international trade matters for the production. We follow the Armington approach (Armington, 1969) to model international trade. In the production process, we assume that in each sector domestically produced and imported goods are imperfect substitutes. At the level of the final good production, the goods from international trade are represented by the composite input B_i—which is an aggregate of Armington goods from all sectors. Once the final good is produced, it is divided between export and domestic consumption given the exogenous foreign prices and under the constraint that trade is balanced in every period. The exported goods and the output produced for the home market are imperfect substitutes as well.

Consumers, who purchase the final output, consume Armington aggregates—that is, combinations of domestic and foreign production.

Government

The model also includes a government, whose role is to collect and redistribute pre-existing taxes (capital and labor taxes, subsidies, and tariffs) and transfers. The governmental budget is initially balanced and stays such throughout the analysis. In our main scenario, the government redistributes the revenues from the carbon tax in a lump-sum fashion.

[3] Note that the models with exogenous growth are commonly specified in KL-E form (Manne et al.,1995; Paltsev et al., 2005; Bosetti et al., 2006).

[4] Karydas and Zhang (2019) use income and on the labor force participation rate data from the Swiss Federal Office of Statistics. They map the time endowment of the households between age groups and income groups according to the same household categories we use. With numbers in brackets corresponding to labor force participation rate for its associated category: Active low (0.15), Active mid (0.1), Active high (0.25), Retired low (0.9), Retired high (0.9).

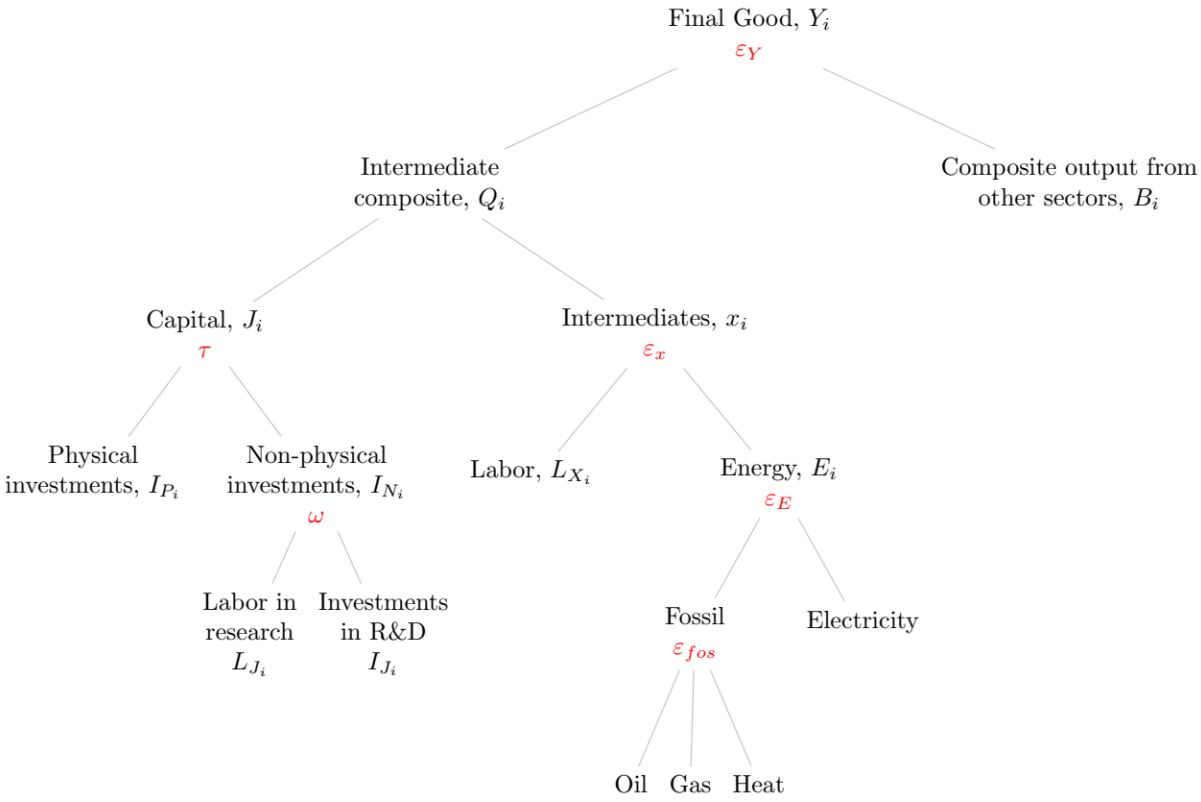

Figure 2. Sectoral production structure of the economy in CITE

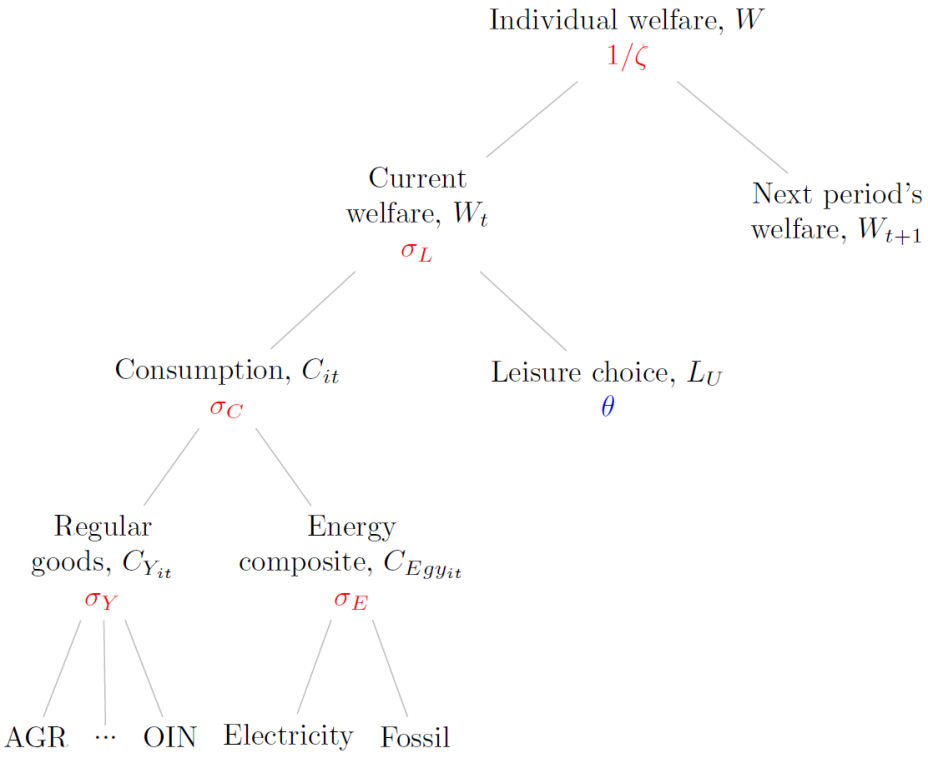

Figure 3: Welfare and demand structure of the economy

6.2.3 Solving the model

In order to solve for the different policy scenarios, we first need to calibrate CITE to the balanced growth path (BGP). Below we expose our main assumptions for the calibration to the BGP as well as our computational strategy to isolate the effect of anticipation.

6.2.4 Key assumptions and the benchmark scenario

The economy is calibrated to follow the BGP with the growth rates that match those of the Swiss economy. The growth rate of the economy, g, is set to 1% per year—which agrees with the average growth rate of GDP per capita in Switzerland in the last two decades.[5]

On the balanced growth path, all sectors grow at the same rate as the entire economy. The growth rate for capital, g_K, however, is different and derives from the expansion-in-variety mechanism of endogenous growth. It relates to the economy's growth rate as $g_K = g^{\kappa}$, where κ is the share of non-capital goods in production across all sectors. Based on the IOT data, we set the value for κ to 0.7, which implies the growth rate of capital equal to 0.7%. The annual rate of return on capital, r, takes the average value of the interest rate set by the Swiss National Bank. The average value for this interest rate over the last 20 years is 0.6%.[6]

Once the economy's growth rate and the interest rate are chosen, the discount rate is determined endogenously by the Keynes-Ramsey rule,

$$g = \left(\frac{1+r}{1+\rho}\frac{P_{C,t}}{P_{C,t+1}}\right)^{\frac{1}{\zeta}},$$

where $P_{C,t}$ is the price of consumption in period t and on the BGP it must hold that $\frac{P_{C,t}}{P_{C,t+1}} = 1+r$. The discount rate can thus be calculated as

$$\rho = \frac{(1+r)^2}{g_C^{\zeta}} - 1.$$

We assume the intertemporal elasticity of substitution, $1/\zeta$, equal to 0.85, which yields a rather conservative discount rate of 0.03%.

Finally, the numerical solution is an approximation of the theoretical model using a finite number of time periods. We employ the method from Lau et al. (2002) to solve for the infinite horizon equilibrium by imposing additional constraints for the terminal period T capital accumulation in the numerical solution. We fix the growth rate of investments in the terminal period to be equal to the output growth rate,

$$\frac{I_T}{I_{T-1}} = \frac{Y_T}{Y_{T-1}}.$$

That is, we impose a constraint on the growth rate of investments only. The actual growth rate of the economy and the terminal level of capital stock are free variables.

[5] According to the World Bank Open Data, the 10- and 20-year average growth rates for GDP per capita in Switzerland are 1% and 1.03% correspondingly. The data can be retrieved from https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG?locations=CH

[6] The current interest rate policy is published on the website of the Swiss National Bank at https://www.snb.ch/en/iabout/stat/statrep/id/current_interest_exchange_rates; the historical data can be retrieved from the Bank for International Settlements at https://www.bis.org/statistics/cbpol.htm.

Computational strategy

The model equilibrium, given our initial SAM and calibration to the balanced growth path, follows from a vector of prices and quantities such that firms maximize their profits, the representative agent maximizes intertemporal utility with respect to the budget constraint, and the adjustment of the price mechanism clears all markets.

We use the General Algebraic Modeling System (GAMS) software and the GAMS/MPSGE higher-level language (Rutherford, 1999) together with the PATH solver (Dirkse and Ferris, 1995) to solve the model as a mixed-complementarity problem.

6.2.5 Scenario analysis

Policy scenarios

We implement policies gradually over the three decades from 2020 to 2050. For all policies, we set a target reduction in CO_2 emissions in proportion to their benchmark value in the first year of the business-as-usual (BAU) scenario. For example, a target of 90% reduction corresponds to a policy that aims at 90% less CO_2 emissions by 2050 than in 2020.[7] We study policies reducing CO_2 emissions from 1% to 95% of their benchmark level.

The key object of our interest is the effect caused by the anticipation of these policies on the dynamics of the macroeconomic variables.[8] The objective is not to propose a set of policies that allows to reach actual climate policy objectives, as the low reduction scenarios are not ambitious enough to reach these objectives, while the most stringent scenarios impose reductions that could lead to negative emissions, if NET and CCS were included in the analysis.

We focus on a carbon tax as the main policy instrument. The tax is paid by the economic sectors as well as final consumers according to the carbon intensity of their consumed energy. The tax is collected by the government and redistributed lump-sum to households. The results of this redistribution are later compared to two alternative ways to recycle the tax income. First, the revenue from the carbon tax is directed to stimulate research in all sectors and thereby facilitate their growth. Second, this revenue is used to reduce the income inequality among the groups of households—in this case, the redistribution is inversely proportional to the level of household income.

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[7] We use the data provided by the World Bank DataBank (available at databank.worldbank.org) to calibrate the CO2 emissions level in the benchmark year to 35.7 Mio tCO2. Hence, in absolute terms, a target of 90% emissions reduction corresponds to 3.57 Mio tCO2. The emission intensity for every sector in the model is determined by its use of fossil fuels. Therefore, the policies refer to energy-related CO2 emissions.

[8] We assume no mechanisms of energy efficiency improvement in the BAU scenario. The economy is initially calibrated to follow a balanced growth path, such that under BAU, the producers have no incentives to improve energy efficiency unless there are policies pushing the production away from dirty energy, or some exogenous technological progress. This makes our results immune to the rightful critique on the uncertainty of the extent of technological progress in the business-as-usual scenario.
There is technological progress in BAU but it is not technological progress specific to energy efficiency improvement. In BAU, the stock of capital increases following the calibration. That is, following the historical average of the increase in Swiss GDP. Investments become more productive as the stock of capital increases and Scientific labor (labor in R&D) is more productive as the stock of capital increases. But one ton of fossil fuel still emits the same amount of CO_2 in 2014 than in 2050.
We also do not assume any carbon capture and storage (CCS) or negative emissions technology (NET), neither in BAU nor under the policies.

We also consider the effect of anticipation under stimulating policies—namely, direct subsidies to clean energy production.

Design of the anticipation effect

We study the effect of anticipation by comparing two different cases of policy implementation. In the first, *anticipation* case, the policy is announced already in 2020 and scheduled for implementation starting in 2030. In the second, *unanticipation* case, the policy is not announced until its implementation in 2030, and thus no adjustments from economic agents are possible beforehand. The differences in macroeconomic dynamics between the two cases then represent the effect of anticipating the policy.[9]

More formally, in order to obtain the effect of anticipation on a given economic variable X (for example, X can represent welfare, GDP, or wages), we compute the difference between the values that X takes under the two implementation schemes. Under the anticipation scheme, at time t_0 the policymaker announces a climate policy to be implemented at time t_1. Agents can thus adjust their optimal choices prior to the implementation. We call the optimal path of X under anticipation X_A. Under the unanticipation scheme, the policymaker does not announce the coming climate policy at t_0, but rather implements it right away at time t_1. Since the agents do not know about the policy in advance, they cannot prepare for the coming regulation at time t_0 and adjust their behavior only at t_1. We call the optimal path of X under unanticipation X_U . The effect of anticipation, Δ_X^A, is thus the difference between the two optimal paths of X under the two schemes,

$$\Delta_X^A = X_A - X_U.$$

In practice, to obtain the unanticipated path X_U, the agents' choices at time t_0 are fixed to their benchmark values (as these values are optimal under BAU). It is only from time t_1 onward that the optimal allocations can deviate from the BAU in order to comply with the policy.[10]

6.3 Results

This section presents the main results of our analysis. First, we state the general effects of policies of different stringency levels. Second, we highlight the anticipation effect of these policies. The objective is not to propose optimal policies, but rather to show the impact of policy announcement on the production side, and on the consumption side of the economy.

6.3.1 Main scenario with lump-sum redistribution

Aggregate economic variables: production side

Carbon policies of any stringency slow down the economic growth—at least in the first two decades. Figure 4 shows the decadal growth of the aggregate output under the implemented policies. In most cases, the growth rates lie below the benchmark level of 1%. At the same time, they hardly ever fall below 0.9%, which indicates slightly slower yet persistent growth. For mild policies (that is, policies that aim at 20% to 50% reduction in CO_2 emissions), higher emission reduction targets directly correspond to a gradual deceleration of the economic

[9] What we call the anticipation period is sometimes called a "phase-in" in the literature (Williams III, 2011). We choose not to use this term to avoid confusion: the policy is already implemented in the "phase-in" period, but reaches its optimal stringency level gradually. In our case, in the anticipation period the policy is not implemented yet.

[10] The values of a variable in the two implementation schemes can differ also in the later periods t_i , $i > 1$. The anticipation effect refers to the deviations in the optimal paths both before and under the policy in comparison to the unanticipation path.

growth. Under more stringent policies, however, the economy mobilizes more of its resources to stimulate the production of final goods. Therefore, even with a low start, the growth rate tends to have an increasing profile and under the 95%-reduction policy reaches 1.075% in 2050.[11]

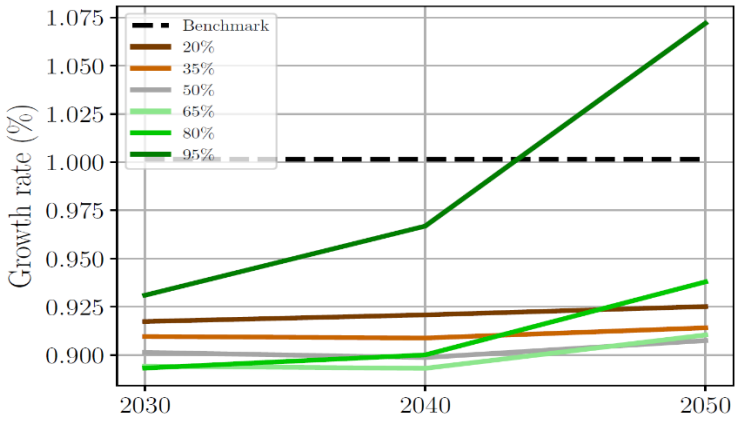
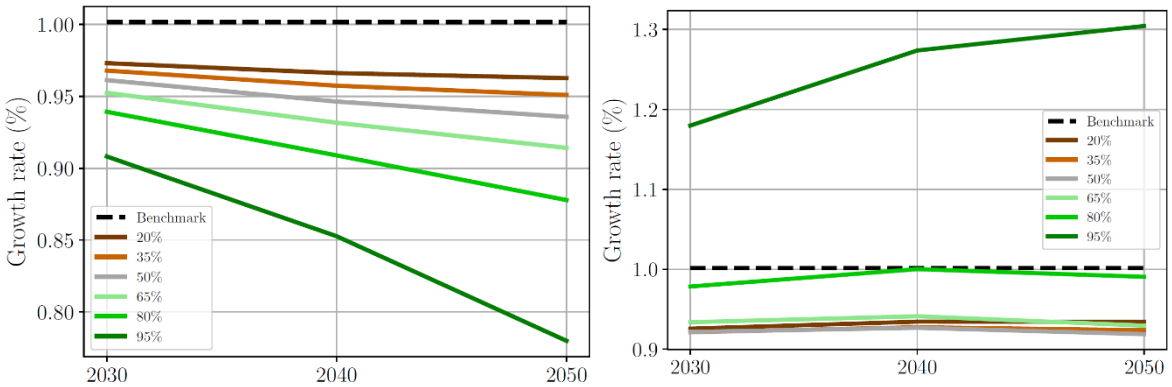


Figure 4: The effect of carbon policies on the aggregate output growth

Figure 5 shows how the effect of the policies on the output growth divides between the consumption (left panel) and investment (right panel). All implemented carbon policies hamper the growth of consumption—in the most extreme case the growth rate falls below 0.8%. Under moderate emissions reductions, the aggregate investment, too, grows slightly slower. When the economy has to cut the emissions drastically, however, the aggregate economic growth requires both higher levels and steeper profiles of investments. Their growth rate thus eventually surpasses the benchmark level—drawing even more resources away from consumption.



[11] In recent years, there has been a decoupling of growth and CO_2 emissions. In the BAU scenario, there are no additional incentives to decoupling since no new policies are implemented, nor are the current rate of taxes changed in time. Without these incentives, the emissions grow at the same rate as the economy. It is thus an assumption of the BAU scenario in our simulations that no decoupling takes place without policy intervention. Under the policy, however, decoupling clearly occurs—growth is reduced by a few percent by 2050, whereas CO_2 emissions are reduced by tens of percent.

Figure 5: The effect of carbon policies on the aggregate consumption growth (left panel) and investments (right panel)

Just like the general effect of policy implementation, the anticipation effect on the total output is more pronounced the stricter the policy. As shown in Figure 6, the output is higher in the first period if the agents expect a carbon regulation to be introduced in the near future. In the case of less stringent policies, the anticipation shifts the production profile towards the earlier periods—the output volumes are higher in the first decade and notably lower in the later decades. Under the most ambitious policy, the advanced knowledge about the regulation ensures higher levels of final production in the first three decades of the modelled period, with the maximal difference of 0.3% in 2020.

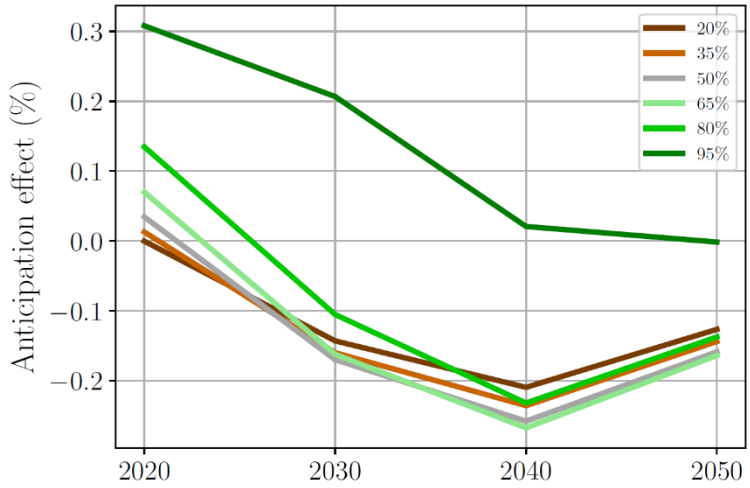


Figure 6: The effect of anticipation on the aggregate output

Figure 7 sheds light on these dynamics by displaying the effects of anticipation on the aggregate consumption (left panel) and investment (right panel). Informed about an upcoming mild policy, the agents shift their consumption in time such that more goods can be consumed beforehand—at the expense of the later consumption subject to carbon taxation. As a result, fewer resources are invested in sectoral growth. Under the stringent policies, however, the opposite effect dominates as households tend to reduce their consumption in the first period in favor of increasing the investments in the economy. These additional investments ensure that the distribution of capital in the economy can start adjusting to a new optimum beforehand. Under the most stringent policy, the initial forgone consumption of over 1% of the total consumption allows the households to consume more in later periods.

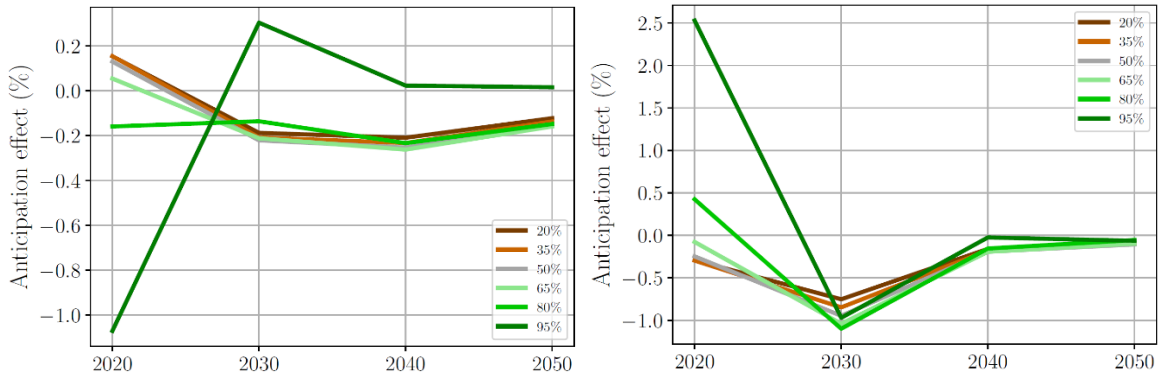


Figure 7: The effect of anticipation on the aggregate consumption (left panel) and investment (right panel)

Sectoral impacts

The impacts of carbon policies are highly asymmetric across the economic sectors. In general, the policies favor the sectors with lower carbon intensity and higher substitution possibilities. The sectors that strongly rely on fossil energy, on the other hand, are left at a disadvantage. Figure 8 shows these diverse sectoral effects on the example of the most stringent policy that aims at 95% emissions reduction. The sector with the highest energy-intensity—transportation—is hit by this policy the strongest and loses over a quarter of its benchmark level of output by 2050. Less carbon-intensive sectors—such as agriculture and chemical sector—end up benefiting from the policy. Their corresponding levels of output rise by 32% and 24% by the end of the modelled period. The industries classified as "other" increase their output level by almost 70% by the time the policy reaches its target.

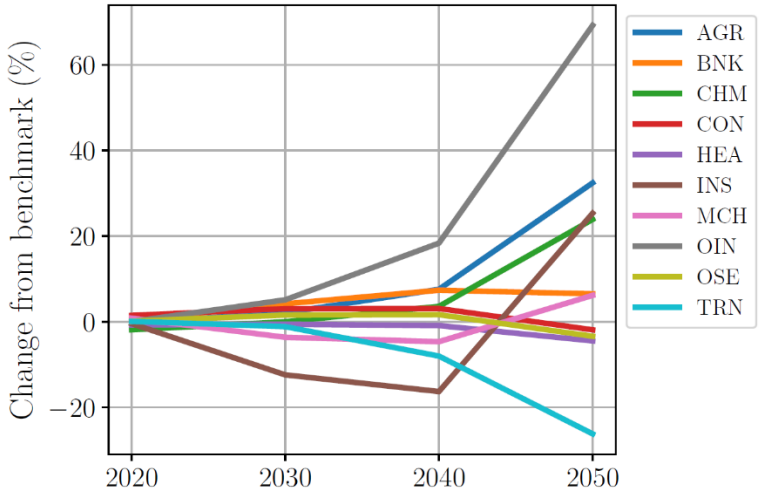


Figure 8: The effect of 95%-reduction policy on the sectoral output

The isolation of the effect of the anticipation period reveals more sophisticated dynamics. Figure 9 provides three demonstrative examples of the effects of anticipation on the sectoral investments and capital accumulation under the policies with increasing targets. One intuitive example of such effects is provided by the banking sector (panel *a)* of Figure 9). Knowing about the upcoming policy and its positive impact on the banking sector, the investors choose to reallocate a part of their resources to this sector in advance (hence the positive anticipation effect on the investment in 2020), and thus much less of such reallocation takes place in the second period (hence the negative anticipation effect on the investment in 2030). By this time, in the case of anticipation, the additional early investment is already transformed into a higher level of capital (hence the positive anticipation effect on capital in 2030).

The fact that the transportation sector has a similar effect of anticipation (panel *b)* of Figure 9) at first seems less intuitive. This sector is energy-intensive and heavily burdened by carbon taxation. Yet, in anticipation of such a policy, the investors decide to stimulate this sector, too, with additional investments. The reason for such a reaction becomes clear when we take into consideration the cross-sectoral structure of the demand in the economy. The transportation sector enjoys relatively high demand from all other sectors, especially those that grow faster under the policy. To maintain the production level such that it meets the demand, the

advanced investment promotes the substitution of capital for energy in this sector. Advance anticipation therefore to a certain extent alleviates the negative effect of a carbon policy.

The insurance sector is an example of a completely opposite effect of anticipation (panel *c)* of Figure 9). Under the stringent carbon policies, the growth of this sector slows down initially and accelerates only in the last modelled decade. The demand from the other sectors for its products is also relatively low—both in the benchmark scenario and under the policies. The sector thus witnesses a divestment already in the first period if the investors anticipate a carbon policy—hence the negative anticipation effect on the investment in 2020, which transfers into a lower capital level in 2030. Without such anticipation, this reaction is triggered directly by the implementation of the policy in the second period.

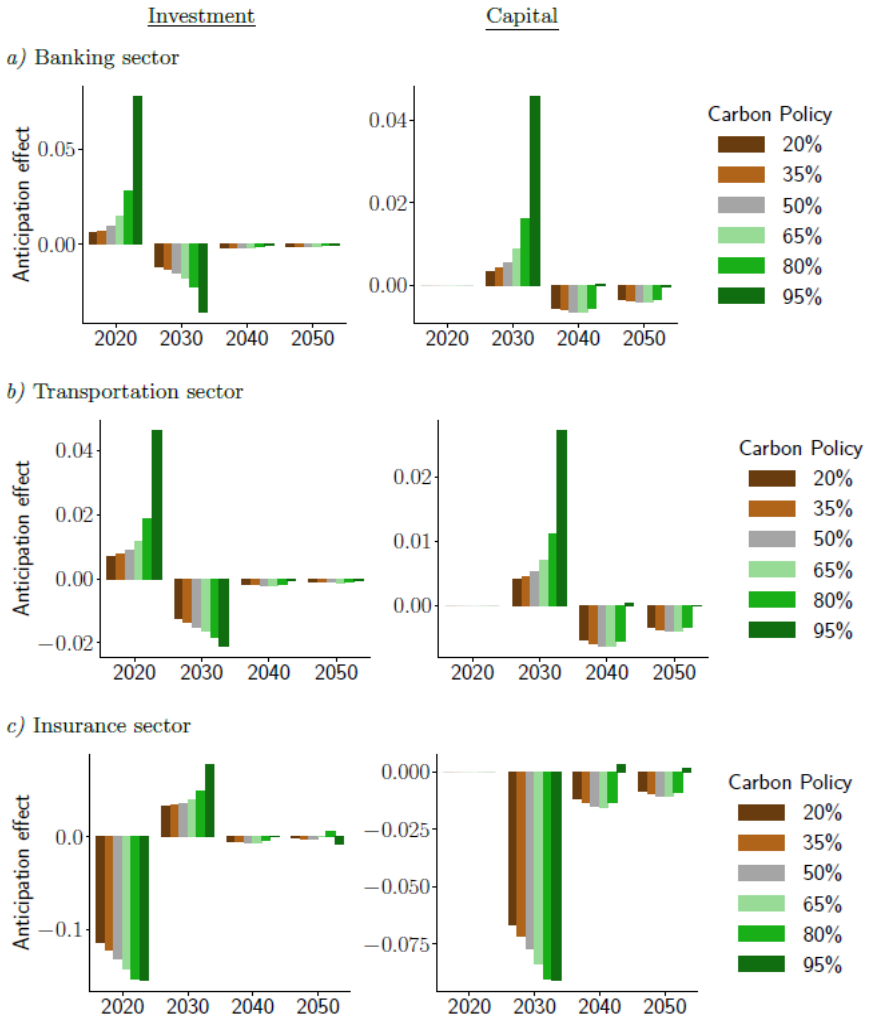


Figure 9: The effect of anticipation on the investment (right panel) and capital accumulation (left panel) in *a)* banking sector, *b)* transportation sector, and *c)* insurance sector

Welfare effects

The aggregate welfare reflects the utility that the households enjoy from both their consumption and leisure. Carbon policies of any stringency lower this welfare by imposing an additional tax distortion on the economy.[12]

Figure 10 shows the highly nonlinear magnitude of such losses with respect to the policies' stringency. For example, a policy that aims at 50% reduction in CO_2 emissions is associated with a loss in welfare of around 0.5%, whereas further reductions to 80% and 95% correspond to roughly two- and a five-fold increase in this cost.

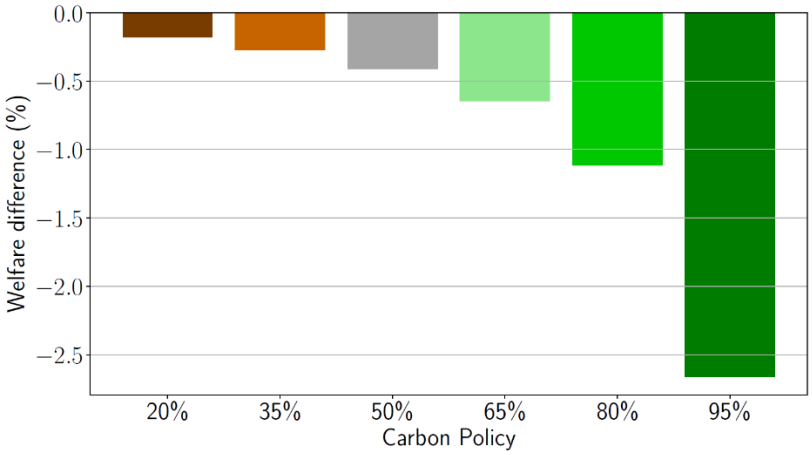


Figure 10: The effect of carbon policies on the aggregate welfare

The effect of anticipation on welfare can be positive or negative as shown in Figure 11. With policy targets becoming more stringent, the anticipation effect changes from clearly negative to strongly positive starting from 90% reduction in CO_2 emissions. The range of the values that such an effect can reach spans from -0.08% to over 0.11%. At first sight, it appears that anticipating the coming carbon tax improves the welfare under stringent policies and harms it otherwise. To better understand the forces that drive such a difference, the dynamics of the anticipation effect has to be explored in more detail.

First, a closer look at the distributional effects of anticipation in Figure 12 reveals that the negative impact entirely relates to the working groups of households (named *Active low*, *Active mid*, and *Active high* in the figure). For these households, labor is the major source of income. In an anticipation of a carbon tax, the households expect the prices for energy and energy-intensive goods to raise and thus they increase their consumption before the actual imposition of the tax burden. These higher consumption levels correspondingly require that they work more hours and enjoy less leisure. This higher labor supply at the same time ensures higher output levels in the first period, as the additional labor mostly flows to production and not to research. The initial increase in consumption is offset by its decrease in the later periods and—together with the lower levels of leisure—leads to a negative aggregate welfare effect, which is slightly more pronounced for the richer working households.

[12] Since we do not assume any carbon capture and storage (CCS) nor any negative emissions technologies (NET), we can interpret the results of our scenarios as upper-bounds of the impact of CO_2 policy on welfare. Our results, nevertheless, should not be affected too strongly by these conservative assumptions because we use an updated estimate of the elasticity of substitution between clean and dirty energy (at 2.0). This elasticity is in the upper tail of the recent results from the empirical literature (Papageorgiou et al., 2017). It reflects the latest technological advances that make dirty and clean energy better substitutes. A good substitutability between and dirty technologies softens the negative effect that CO_2-restriction policies have on welfare compared to a BAU scenario.

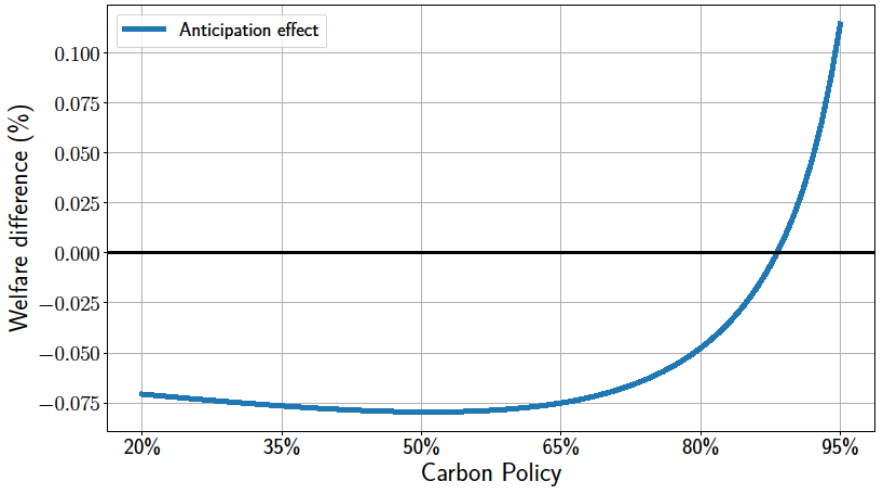


Figure 11: The effect of anticipation on the aggregate welfare

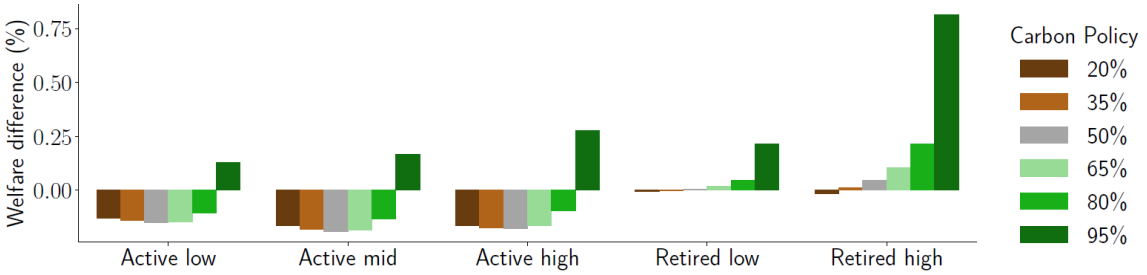


Figure 12: The effect of anticipation on welfare across the five groups of households

As the policies become more stringent, another effect starts dominating. Most of the adjustment on the production side of the economy to the upcoming carbon policy is made through the redistribution of the investments—and, subsequently, capital—from carbon-intensive sectors to "cleaner" sectors with lower tax burden and thus higher profitability. Capital owners can thus earn notably higher returns on investment if they anticipate a stringent carbon policy. Given that capital returns comprise a large share of income for the richer and retired households, the effect of such adjustments is highly regressive—even though it benefits all household groups.

6.3.2 Other redistribution schemes

Redistribution inverse-proportional to income

As shown above and also highlighted by the existing literature, stringent policies (or anticipation thereof) might turn out disadvantageous for less affluent households. We attempt to alleviate this effect by designing a tax revenue recycling scheme that distributes the revenues from a carbon tax in *inverse proportion* to the households' income level. In its naïve interpretation, such a scheme should utilize the tax revenues to reduce income inequality across the households.

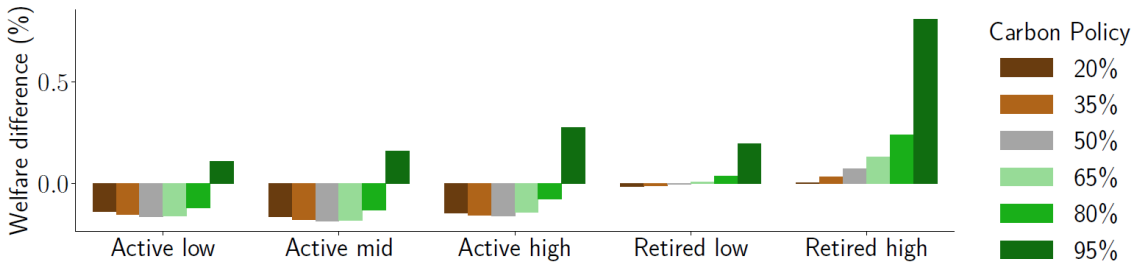


Figure 13: The effect of anticipation on welfare across the five groups of households under inverse-proportional redistribution scheme

As Figure 13 demonstrates, the anticipation effect for policies with the inverse-proportional redistribution scheme is indistinguishable from that in the case of lump-sum redistribution. That is, if the agents can predict an upcoming policy, they can prepare for the changing economic conditions by modifying their consumption, leisure, and investment choices in the same way as elaborated above. On the one hand, the inverse-proportional redistribution helps the poorer households maintain their consumption levels. Yet, in anticipation of such a policy, capital owners adapt their investment decisions even more intensely, and the anticipation effect of the strict carbon policies stays regressive.

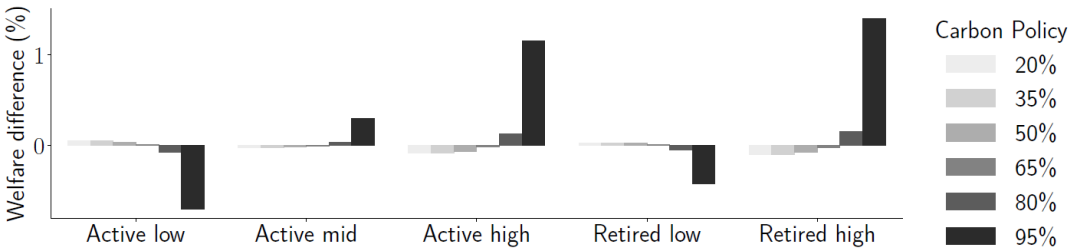


Figure 14: The difference in welfare between the inverse-proportional and lump-sum redistribution schemes across household groups

This dynamic becomes even more evident when the absolute effects of the carbon policies are considered. Figure 14 shows the difference in absolute welfare impacts between the policies with inverse-proportional and lump-sum redistribution schemes. The inverse-proportional redistribution strategy is designed to favor the poorest category of households. Such an effect indeed occurs under policies with low emissions targets, though on a minor scale. Under stringent policy targets, however, the investments in the economy shift much stronger towards less carbon-intensive sectors, leaving the owners of the capital better-off. The inverse-proportional reallocation scheme can thus benefit the richer groups of households and yet leave the poorer groups at a disadvantage.

Redistribution to R&D in all sectors

Carbon tax revenues can also be recycled to foster the growth of the whole economy and thus alleviate the tax burden on carbon-intensive sectors. In this alternative redistribution scheme, the government uses carbon tax revenues to *subsidize* research and development in all economic sectors. Through the endogenous growth mechanism, these subsidies may

stimulate the accumulation of capital in every sector and subsequently the overall economic growth.

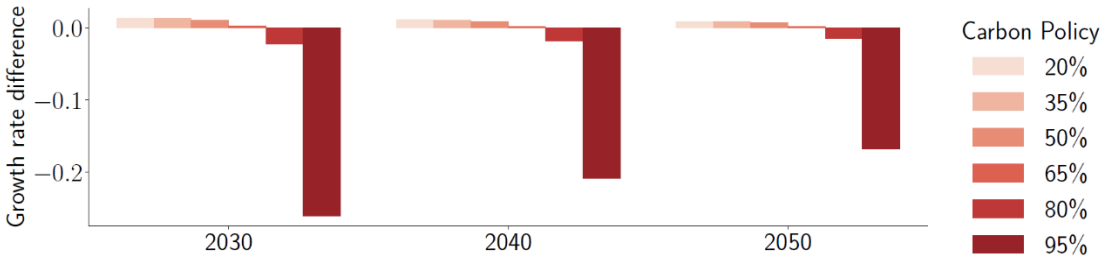


Figure 15: The difference in growth rate of *consumption* between the R&D and lump-sum redistribution schemes

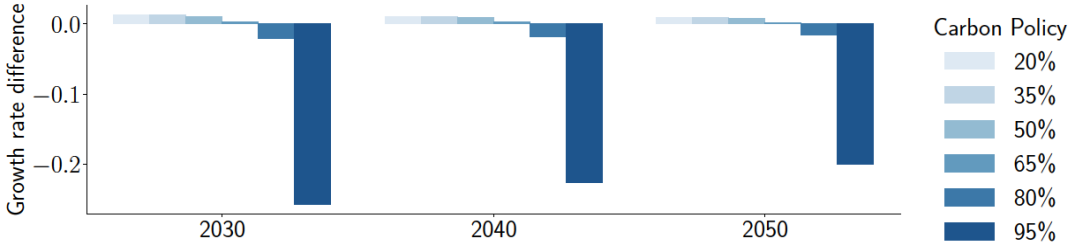


Figure 16. The difference in growth rate of *output* between the R&D and lump-sum redistribution schemes

The effects of such stimulation might or might not have these expected effects. Figure 15 and Figure 16 show the differences between R&D and lump-sum redistribution for the growth rates of GDP and consumption correspondingly. For relatively mild policies, an R&D-oriented redistribution scheme indeed enables slightly higher economic growth and also faster growth of consumption. In the most stringent cases, however, the effect is reverse. As tax revenues in this setting support sectoral growth, much less investment gets allocated to sectoral capital.[13] At the same time the policy targets are reached with significantly lower level of carbon tax than under lump-sum redistribution. The corresponding lower tax revenues convert into lower subsidies and thus slower economic growth.

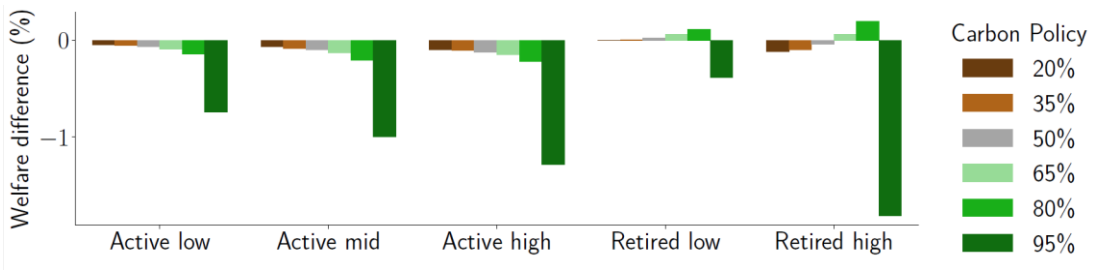


Figure 17: The effect of anticipation on welfare across the five groups of households under R&D redistribution scheme

[13] In the most extreme scenario of 95% emissions reduction, the investors cut their investments by almost 10% in anticipation of this policy.

Figure 17 shows the effect of the anticipation of carbon policies with R&D redistribution. Because this redistribution scheme hampers the investment incentives, the anticipation effect for such strict policies can turn strongly negative.

6.3.3 A subsidy policy to clean energy production

One policy that is typically considered as an alternative to dirty energy taxation is a subsidy to clean energy. Such a subsidy is meant to render the production of clean energy more competitive and thereby promote clean energy use. As an immediate effect, such stimulation allows the producer to lower the prices and hence increase the production volumes supplied to the market. Our analysis suggests that the production of the clean energy sector indeed responds positively and very strongly to a subsidy—that is, its volume rises significantly immediately after the introduction of such a policy.

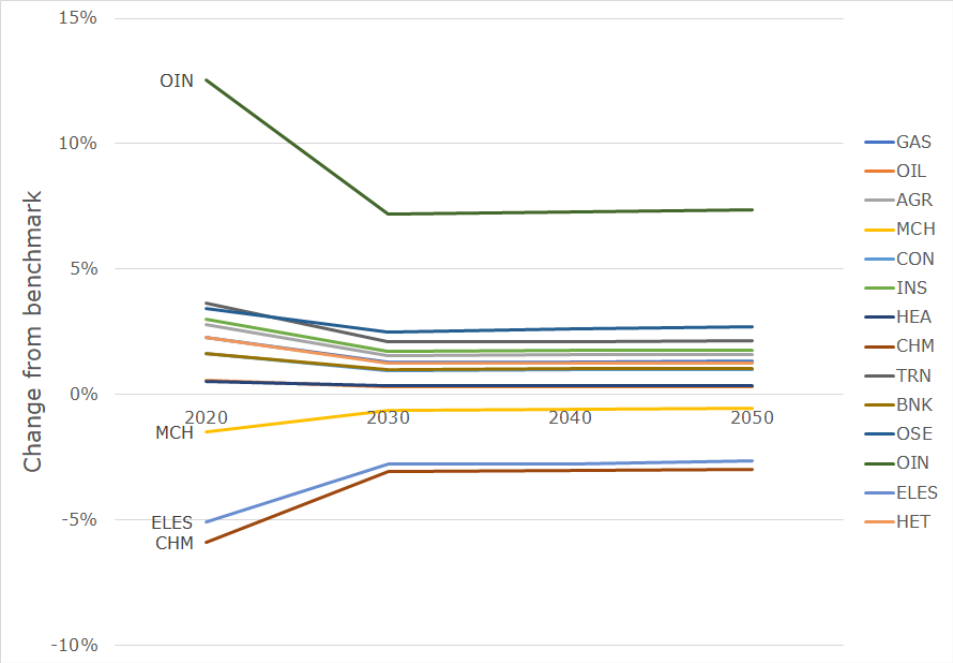


Figure 18: The effect of 1% subsidy to sectoral production on the investment level in various sectors

This policy, however, draws the resources away from the investment in this sector—even though investments to green energy continue growing over time, they are notably lower than the benchmark level. Figure 18 shows that such an effect occurs in several sectors (namely, in chemical, electricity, and machinery sectors) as a response to production subsidy. In the endogenous growth framework, the expansion of production due to higher inputs use occurs in parallel with capital accumulation through investments. A subsidy to production thus initially attracts more resources to immediate production at the expense of investment and future growth. The results, therefore, suggest that a subsidy to the production of green energy alone does not prove effective in achieving low-carbon targets. Having the expected effect of fostering the production, it ends up hampering the sector's growth.

6.4 Conclusions

We study the role of the anticipation period of climate policies in a numerical model of general equilibrium with endogenous growth, heterogeneous households with labor-leisure choice, and multiple economic sectors. The anticipation period is defined as the period of time the

policymaker gives to the agents in the economy to adjust their decisions before the implementation of a policy. On an example of the Swiss economy, we analyze the implications of such an anticipation period for welfare and economic growth at various stringency levels of carbon policy.

We find that both the magnitude and sign of the effect of policy anticipation may vary depending on the strength of the underlying economic incentives. Under moderate policy targets, the incentive to increase the immediate consumption dominates and renders the aggregate welfare effect negative. In anticipation of more stringent carbon policies, the agents more actively redistribute their investments beforehand and achieve a more profitable allocation under the upcoming policies. Thus, the given opportunity to adjust in advance turns out beneficial on the aggregate level.

An equally important result is that the knowledge about future policies can have a varying effect on different groups of households and can amplify the existing income inequality. The households' sources of income determine their ability to prepare and adapt to the upcoming taxation. The dynamics of the economy in anticipation of a carbon tax might change the economic environment against the working and poorer households, who might find themselves working more in an attempt to maintain their consumption level. For the richer and retired groups, on the contrary, additional capital earnings due to advance adjustments of their investment strategies partially offset the tax burden. The redistribution of the tax revenues directly to the consumers does not alleviate these disparities. Even distributing higher shares of tax revenues to the less affluent households does not change these dynamics—instead, it reinforces the advance adjustments to the policies.

7 Discussion of findings

7.1 Overall picture

The findings from this research project underline the importance of expectations and the respective need to take them into account in modelling and economic research overall. First, expectations play a crucial role in determining the development path of an economy. Second, credible signaling in order to shape expectations can then help to align investments and reduce uncertainties.

From theory, we can see that the expectations can be decisive for the equilibrium selection and that a policy that communicates a course towards green energy can direct the economy towards energy transition. The empirical analyses indicate that both, consumers and firms actively take into account signals from the government with respect to future policies. This calls for an active role of the government in shaping such expectations. Thanks to early information, individuals and firms can adjust their decision-making process and thereby save costs. What is more, there may be several effects of self-fulfilling prophecies based on the influence of expectations. First, optimistic expectations about the general economic development could help to shift the economy towards a higher equilibrium. Second, the announcement of a policy could induce individuals and firms to adapt early to the new framework, potentially increasing the number of supporters for the actual implementation of the very same policy.

The combination of theoretical modelling and empirical analyses (projects 1 and 3) allows us to discuss the macroeconomic implications with a more realistic perspective. Thanks to using the data from a representative survey in Switzerland (P1) and setting up our own experiment (P2) we can control for a variety of socioeconomic variables and external factors, making the analyses more robust. The empirical method we propose in P3 is new and has to be further tested for robustness. The method and data collection might be useful for multiple other analyses addressing expectations of small companies not listed at the stock markets (where expectations are usually estimated from the asset prices).

Finally, the numerical analysis in P4 allows us to identify and closely explore the potential effects of policy expectations in the Swiss economy and discuss the impact of different policy instruments.

7.2 Policy Implications

In P1 we look at expectations about the general economic development built on the theoretical foundation of Bretschger and Schaefer (2017). In P2 we look at expectations on the consumer side and in P3 at firms. Thus, our analysis covers three different kinds of expectations that are of high relevance for policymakers. First, expectations about the general development influence the growth path of an economy. Thus, they should be taken into account in growth projections and respective cost estimations of policies.

Second, individuals adjust their investment decisions if they expect a changing policy framework. While the importance of information on future policies is widely propagated for monetary and R&D policymaking, there has been no work on the effect of early announcements for individuals. Policymakers ought to be aware of the effects that early policy announcements can have.

Similarly, and third, for entrepreneurs, early knowledge about future policies seems to influence the assessment of a business case and the decision to enter a market. Hence, credible signaling has the potential to influence the speed of the energy transition.

The numerical analysis in P4 confirms that the anticipated policy can bring the economy to a different equilibrium in comparison to its unanticipated analogue. The results underscore the importance of considering the broad set of economic forces and incentives triggered by the anticipation of a policy. Careful policy implementation would thus consider the interests of various groups of economic agents—including the producers that win or lose from the policy and especially the households that might or might not be able to use the advanced information in their favor.

With regards to future research we, thus, propose that the announcement or signaling of policies is taken into account when analyzing the costs and feedback effect of policies. Current research primarily focuses on effects in the post-enactment period (e.g., Béland et al, 2019), whereas our research calls for an analysis of the pre-enactment period, too.

7.3 Additional Remarks with regards to the Swiss Case

The Swiss government is very trustworthy: according to OECD (2017), trust in political institutions is highest in Switzerland compared to all OECD countries. Thus, in light of the

findings of P2 and P3, Swiss policymakers may want to consider (more) actively using signals in order to give industries and individuals time to adapt.

This fact also allows us to juxtapose the two clear cases of knowing and not knowing about a policy in advance in P4. The analysis of the Swiss case suggests that announcing a policy in advance might indeed help the economy to prepare and adapt to the tax burden better. At the same time, this burden might be carried disproportionally as some households end up in a better position than the other. In particular, the expectation of a policy can induce adverse economic conditions for the households whose main source of income is their wage. As the analysis shows, this effect is not easy to offset by redistributing tax revenues. On the production side, too, some sectors might bear higher costs in anticipation of policies as the investment flows towards not only more profitable and cleaner sectors but also to the sectors in higher demand and lower substitution possibilities.

8 Conclusions

In this research project, we analyze the role of expectations for different actors in the economy. We apply theoretical modelling and empirical analyses and integrated policy expectations in a CGE model calibrated for Switzerland.

As proposed in milestone 1, we develop a holistic theoretical model to analyze the role of expectations (P1). With P2 we then analyze the role of an active government and respective signaling to coordinate expectations, as defined in milestone 2.

With the empirical analyses in P1, P2, and P3 we vastly cover different aspects of expectations on consumer and firm behavior as defined in milestone 3.

The integration of anticipation effects into a large-scale dynamic computable general equilibrium model calibrated for the Swiss economy (P4) with the aim to simulate policy experiments reflects milestone 4.

9 Outlook and next steps

The findings of the research project clearly demonstrate that expectations play a significant role in shaping the development of an economy. While the defined research questions have been comprehensively addressed within this project, there are still multiple research questions to be followed up with. In particular, we believe that it could be very interesting to investigate whether the acceptance of policies and the support for the enactment actually increases when a policy is announced early since the target groups had time to align to the policy. Also, analyzing different types and timing of policy signals could be interesting follow-up projects.

The current working paper versions of P2, P3, and P4 will be developed further and submitted to highly ranked academic journals. The current state of research of P4 was presented at International Workshop on Energy, Innovation, and Growth in September 2020 in Zurich, Switzerland. It will also be submitted to presentation at the EAERE annual conference in 2021.

The current state of research of P3 will be presented at the SURED conference in October 2020 in Ascona, Switzerland.

10 National and international cooperation

The experiment in SHEDS 2018 was designed and implemented in collaboration with the University of Neuchâtel, the Paul Scherrer Institute (PSI), and the Zurich University of Applied Sciences (ZHAW).

11 Communication

Not applicable

12 Publications

Schaefer, A. and Stünzi, A (2019). The impact of green preferences on the relevance of history versus expectations. Environment and Development Economics.

Stünzi, A. and Schubert, I. (2019) Retrofitting for good: insights from the Swiss Household Energy Demand Survey. ETH Energy Blog. https://blogs.ethz.ch/energy/swiss-household-energy-demand-survey/

Hörler, R., Stünzi, A., Patt, A., del Duce A. (2020). What are the factors and needs promoting mobility-as-a-service? Findings from the Swiss Household Energy Demand Survey (SHEDS). European Transport Research Review, 12 (27).

Stünzi, A (2020). Governing climate change and humanitarian migration: the role of expectations and equity. Doctoral Dissertation. ETH Zurich

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14 Appendix

Not applicable