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The macro-financial effects of Climate Policy Risk: evidence from Switzerland

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Abstract

This paper quantifies empirically the macroeconomic and financial effects of Climate Policy Risk (CPR) in Switzerland. To do so, I develop a new CPR index using text analysis techniques on a large dataset of Swiss media articles. The identification of CPR shocks is achieved by using narrative restrictions around events which are likely to have coincided with an increase in the probability of adopting tighter climate policies. I find that CPR shocks are associated with a significant decline in real GDP and a decline in firm-level CO2 emissions. Using firm-level equity price data and rolling linear panel regressions, I document that CPR is increasingly reflected in asset prices. I further find that CO2-intensive firms perform significantly worse than their greener counterparts following events which increased transition risk. The results are in line with recent theoretical contributions.

Keywords Climate policy risk, Transition risk, Event-study, Narrative restrictions, Business cycles, Asset prices

JEL Classification G11, G18, Q54

1 Introduction

Climate change concerns and in particular so-called transition risks arising from a possible transition to a low-carbon economy are becoming increasingly relevant for central banks (see, for example, Rudebusch et al. (2019); Batten et al. (2020); Maechler and Moser (2019)). For example, a mispricing of climate-related risks could have important implications for financial stability in the case of a sudden implementation of stringent climate policies (Battiston et al., 2021). Furthermore, the uncertainty surrounding the transition path can also have important macro-financial implications. Fried et al. (2022) develop a dynamic general equilibrium model to quantify the macroeconomic impacts of climate policy transition risk. They show that transition risk (defined as the future probability of adopting a carbon tax) can affect the composition of capital and reduce output. Climate considerations are also becoming increasingly relevant for investors. Krueger et al. (2020) survey active investment managers and find that a large proportion of investors believe that climate change can have important implications for their portfolios. Pastor et al. (2021) develop a general equilibrium model of sustainable investing and show that green assets can outperform brown ones when concerns about climate change rise unexpectedly, and link this to the investors' preference for sustainability.

Against this backdrop, the aim of this paper is to empirically quantify the macroeconomic and financial effects of CPR in Switzerland. A key novelty is to identify CPR shocks using narrative restrictions around events which are likely to have coincided with an increase in the probability of adopting tighter climate policies. At the macroeconomic level, I find that CPR shocks are associated with

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a significant decline in real GDP and lower firm-level CO2 emissions. In terms of financial response, I document that the equity price of firms with low within-sector CO2 has outperformed that of browner firms when CPR rises unexpectedly over the last decade, using both linear panel regressions and an event-study approach.

To quantify risks related to climate policies, I develop a new CPR index for Switzerland using text analysis techniques on a large number of Swiss media articles. The focus on Switzerland differs from most of the existing literature, but seems particularly relevant as Switzerland systematically ranks among the countries with the highest Environmental Policy Stringency index,[1] which suggests that transition risk may be particularly important there (see Additional file 1: Figure G.1). To build the index, I adopt an approach similar to that of Baker et al. (2016) in the context Economic Policy Uncertainty and recently applied to US Climate Policy Uncertainty in Gavriilidis (2021). The resulting index rises around a number of important climate policy-related events such as international climate agreements, Intergovernmental Panel on Climate Change (IPCC) and other scientific reports, or development related to the introduction or revocation of climate policies. While being largely correlated with the US Climate Policy Uncertainty index from Gavriilidis (2021), the Swiss CPR index also displays distinct behaviours and allows to identify a number of domestic transition risk events that would not have been possible to capture with a foreign index. Furthermore, the index is available at the daily frequency. I argue that the CPR index is a reasonable measure capturing the public awareness to a wide array of risks related to climate policies which are particularly relevant from a Swiss perspective.

In Fried et al. (2022), an increase in climate transition risk corresponds to an increase in the probability of adopting a higher carbon tax. As the empirical equivalent to this concept is challenging to find, I propose to use the daily CPR index to narratively and manually identify a number of events which are likely to have coincided with an increase in the probability of adopting stricter climate policies (for example, the so-called "green wave" at the Swiss federal elections), and at the same time received an important media coverage. The approach is then to leverage on these so-called transition risk events to empirically test the theoretical predictions from Fried et al. (2022).

At the macroeconomic level, I estimate a monthly VAR for Switzerland over the period 2000M1 to 2020M2 and adopt a shock-based identification scheme à la Ludvigson et al. (2021) using narrative restrictions around the transition risk events. CPR shocks are identified by imposing that they contribute meaningfully to the unexpected variations in the CPR index around the transition risk events. In line with Fried et al. (2022), the narratively identified CPR shocks are associated with a significant drop in real GDP, and I find suggestive evidence that a higher CPR coincides with lower subsequent CO2 emissions at the firm level. These results are robust to different sample specifications and identification schemes.

Regarding the financial response, the VAR exercise finds little average effects of CPR shocks on equity prices and no significant heterogeneous effects on green versus brown equity indices. I conjecture that this lack of result may be driven by the fact that investors have only recently started to incorporate climate-related considerations in their portfolio decisions. To investigate this time dimension, I define a green minus brown (GMB) portfolio which goes long (short) in firms with relatively low (high) within-sector CO2 emissions. The underlying argument is that, if CPR is priced, the GMB portfolio should rise in value when CPR increases, as green firms are expected to fare better than browner ones. Using rolling panel linear regressions, I find that, over the last 10 years, this portfolio is associated with significantly higher returns when CPR rises unexpectedly, in line with the predictions from Pastor et al. (2021). However, such a portfolio does not provide higher returns in the beginning of the sample (2000–2012). I interpret this as suggestive evidence that CPR is increasingly reflected in asset prices in Switzerland.

The relevance of CPR for asset prices is further confirmed by using an event-study approach combined with Jordà (2005)-type local projections. Following events which arguably increased the probability of adopting stricter policies, the equity prices of firms with relatively high CO2 emissions tend to drop more than their greener counterparts. The monthly results suggest that the drop is persistent, as the equity price of brown firms is around 4 per cent smaller 12 months after the event. Overall, the results suggest that transition risk has macroeconomic implications, and that asset prices increasingly reflect CPR considerations, as predicted theoretically in Fried et al. (2022) and Pastor et al. (2021).

This paper is structured as follows. Section 2 surveys related literature. Section 3 describes the data sources. Section 4 details and discusses the construction of the CPR index. Section 5 reports the macroeconomic effects of CPR shocks. Section 6 focuses on the financial response of asset prices. Section 7 concludes.

[1] The Environment Policy Stringency index is developed by the OECD and "measures the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behaviour". More information here: https://www.oecd-ilibrary.org/environment/data/oecd-environmentstatistics/environmental-policy-stringency-index 2bc0bb80-en.

2 Related literature

This paper is related to the growing literature investigating the macroeconomic implications of risks related to climate change and in particular those related to the transition towards a greener economy (so-called transition risks). Känzig (2021), Berthold et al. (2023), and Mangiante (2023) focus on the economic effects of carbon pricing policies in the EU Exchange Traded System, whereas Konradt and di Mauro (2021), Metcalf (2019), and Metcalf and Stock (2020) focus on carbon taxes. Fried et al. (2022) develop a dynamic general equilibrium model to quantify the macroeconomic impacts of climate policy transition risk. They show that transition risk reduces emissions by reducing the expected returns of fossil capital, but also lead to lower output overall. Ferrari and Pagliari (2021) develop a two-country two-sector (brown and green) DSGE model and explore the cross-country implications of climate-related policies. At a general level, this work is related to the recent effort of central banks to incorporate climate considerations to help foster macroeconomic and financial stability (e.g. Rudebusch et al. (2019); Batten et al. (2020)).

By focusing on the financial effects of CPR, this paper is also related to the climate finance literature (see Giglio et al. (2021) for a survey). Bolton and Kacperczyk (2021a) investigate investors' attention to carbon risk and find that higher carbon emissions are associated with higher expected returns in the US stock market. Bolton and Kacperczyk (2021b) confirm these results more globally by documenting the existence of a carbon premium in all sectors over three continents, namely Asia, Europe and North America. They further argue that the premium has increased in importance since the Paris agreement. In line with this, Alessi et al. (2021) find the existence of a greenium (a negative risk premium) for firms which are more environmentally friendly and transparent. Choi et al. (2020) document that the stock price of low-emission firms tend to outperform when the weather is abnormally warm. On the other hand, Hong et al. (2019) find that stock prices tend to underreact to physical climate risks. Theoretically, Pastor et al. (2021) propose an equilibrium model of sustainable investing. Their key result is that, in equilibrium, green assets have lower expected returns because investors value their (non-pecuniary) environment, social and governance (ESG) characteristics. However, green assets outperform when there are positive shocks to the ESG factor. Ardia et al. (2022) confirm this empirically by showing that US green firms tend to outperform brown firms when climate change concerns change unexpectedly.

On the methodological front, the construction of the index connects with a literature which uses text analysis methods to produce new proxies of economic concepts. For instance, Baker et al. (2016) develop an index of Economic Policy Uncertainty using 10 leading US newspapers. Other examples of text-based indices include Gentzkow and Shapiro (2010), Hoberg and Phillips (2010), and Boudoukh et al. (2013). Finally, Gavriilidis (2021) adapts the approach from Baker et al. (2016) to construct an index of Climate Policy Uncertainty.

3 Data

3.1 Newspapers data

I rely on a novel database called Swissdox to construct the CPR index. The database is comprehensive and essentially covers the universe of published articles in Switzerland.[2] I focus on the main Swiss outlets in French and German. German-written newspapers include *Neue Zürcher Zeitung, Tages Anzeiger, Blick,* and *20 Minuten.* French-written newspapers include *Le Temps, 24 heures, Tribune de Genève,* and *Le Matin.* The sample starts in January 2000 and ends in October 2022. For all newspapers, I focus on printed articles. The final dataset is made of roughly 3.75 million articles, out of which 69.8% are in German and 30.2% are in French, in line with the language distribution of Switzerland. Additional file 1: Table B.1 in Appendix B provides the number of articles by media outlets. Additional file 1: Figure B.2 displays the time series of the number of articles by year and language.

3.2 Macroeconomic data

I collect macroeconomic data at the monthly frequency on real GDP, equity prices, the consumer price index and the policy rate data for Switzerland using Datastream. I further consider measures of Economic Policy Uncertainty for Switzerland and the US. The monthly sample is restricted by the availability of the CPR index and runs from 2000M1 to 2020M2. Monthly real GDP is obtained by interpolating quarterly level data using a shape-preserving piecewise cubic interpolation as in Miranda-Agrippino and Rey (2020). Additional file 1: Figure B.1 in Appendix B provides a graphical representation of the data.

3.3 Firm-level data

I collect firm-level equity price data from Datastream at the daily frequency for all public firms in the Swiss Performance Index (SPI). The composition of the index is dynamically adjusted. I complement the equity price data with firm-level measures for CO2 emissions, denoted by

[2] The media data is made available through Swissdox@LiRI by the Linguistic Research Infrastructure of the University of Zurich (see https://t.uzh.ch/1hI for more information). I thank the Swiss Institute of Applied Economics of the University of Lausanne (CREA) for giving me access to this data.

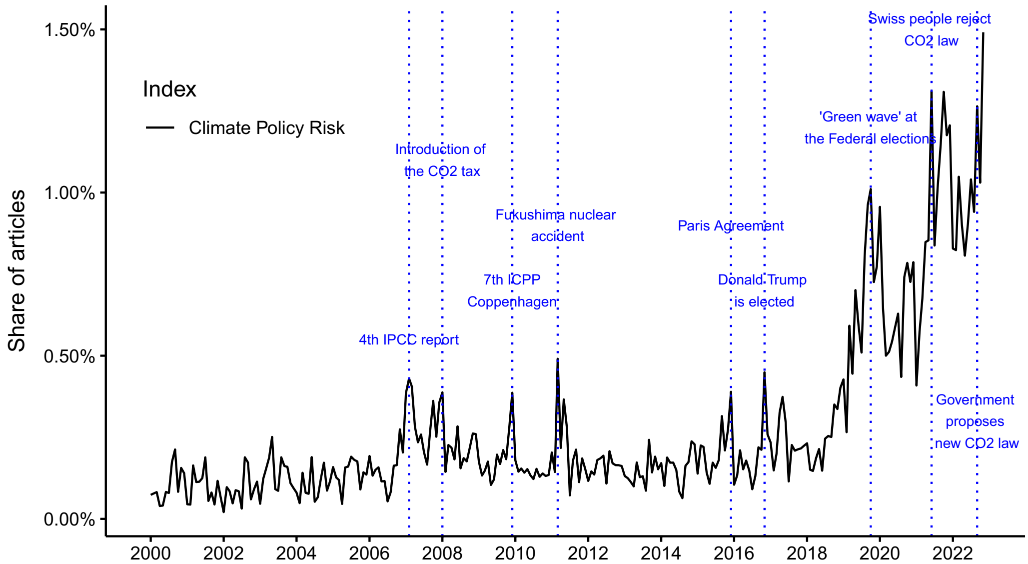

Fig. 1 Climate Policy Risk index in Switzerland. *Note*: This figure displays the CPR index for Switzerland over the period 2000–2020. The frequency here is monthly, but the index is also available at the daily frequency

$CO2_{i,t}$. Specifically, I consider both scope 1 and scope 2 CO2 emissions at the firm level from Datastream and available at the annual frequency. Scope 1 emissions include greenhouse gases (GHG) emissions that emanate from the operation of capital directly owned by the firms. Scope 2 emissions are indirect emissions associated with the purchase of electricity, steam, heat or cooling. As the two measures are complementary, the main measure of interest is the sum of scope 1 and scope 2 emissions. Finally, I consider a vector $X_{i,t}$ constituted by a number of firm-level controls available at the quarterly frequency from Datastream, namely a measure of leverage (measured as the ratio of total debt to assets), a measure of profitability (sales growth) and a measure of size (total assets). In the full sample, there are 217 unique firms at the end of 2022 and 1,024,967 observations. The coverage of CO2 data is equal to 45.2%. Additional file 1: Table B.2 provides summary statistics at the sector level.

4 An index of Climate Policy Risk

4.1 Methodology

To build the CPR index, I adopt an approach similar to that of Baker et al. (2016) in the context of Economic Policy Uncertainty and recently applied to US Climate Policy Uncertainty in Gavriilidis (2021). In particular, I search for articles which contain keywords related to climate change (such as climate, CO2, greenhouse gases and renewable energy). I then refine the search by adding terms related to policy (such as government, law, parliament, regulation, federal and Bern). Finally, I add keywords related to risk and uncertainty (risk, uncertainty, doubt, unanticipated, unstable, etc.). Additional file 1: Appendix A provides the list of keywords used. I then divide the number of articles that contain keywords related to climate, policy and risk by the total number of articles in each month or day. The resulting CPR index is available at both the daily and monthly frequency.

4.2 Validation of the index

The resulting monthly CPR index is displayed in Figure 1. The index rises around a number of important climate policy-related events such as international climate agreements, IPCC and other scientific reports, or developments related to the introduction or revocation of climate policies. The index also spikes around a number of domestic events, such as the proposal of a new CO2 law by the Swiss Federal council in 2022M9, the rejection of the CO2 law by Swiss people in 2021M6, or in 2019M10, a period that coincides with a "green wave" at the Swiss federal elections. It is in general always possible to link a spike to a climate-related event, which suggests that the index does not identify false positives and that the keywords considered are suitable for the exercise. Generally speaking, the index appears to be effective at identifying a wide array of climate-related risks as well as periods which are likely to have coincided with increases in transition risk.

In Additional file 1: Figure B.3 of Appendix B, I compare the (scaled) CPR with the US Climate Policy Uncertainty index from Gavriilidis (2021). The two series turn out to be closely related with a correlation of 0.74, as can be expected as climate change is a global phenomenon. However, they also diverge during certain periods, for example around the election of Donald Trump which appears to be a significantly larger shock for the US Climate Policy Uncertainty. Similarly, the spike related to the rejection of the CO2 law is virtually absent from the US CPU. I interpret this as evidence that the index captures transition risk that is most relevant to Switzerland. This is particularly important because the macro-financial economic data that is considered in the analysis relate to firms that are headquartered in Switzerland, and thus are exposed to Swiss-specific policy risk. In Section 4.4, we will also see that the index is particularly helpful in identifying transition risk events related to domestic policies that would not be captured using other existing indices.

4.3 Discussion

I now discuss the interpretation of the CPR index. Broadly defined, climate-related policy risks include the economic risks induced by the transition towards a greener economy. As a result, this does not only include the risks stemming from the discussion or the implementation of stricter climate policies (e.g. the "green wave" at the federal elections or the introduction of a CO2 tax), but also the uncertainty created by the (possible) revocation or loosening of existing climate policies (e.g. the election of Donald Trump or the rejection of a CO2 law). Similarly to the Economic Policy Uncertainty index from Baker et al. (2016), the media-based index captures variations in the *public awareness* of climate-related policy risks. This notably allows to capture a large number of events, not only restricted to the discussion, implementation or revocation of climate policies. For example, the index captures the nuclear accident in Fukushima in 2011M3 or the release of the 4th IPCC report. Given that transition risk is a multifaceted concept with no single and comprehensive definition, the flexibility granted by the keyword-based approach turns out to be a great advantage. Furthermore, focusing on newspapers is in line with Nimark and Pitschner (2019) who highlight the importance of the media in updating consumers and investors' view on the state of the world. Several studies have also confirmed the importance of media in increasing public awareness regarding environmental issues (see, for example, Boykoff and Rajan (2007); Sampei and Aoyagi-Usui (2009)).

In Fried et al. (2022), transition risk shocks are defined as an exogenous increase in the probability of adopting a stricter carbon tax policy. How does this compare with the CPR index? Figure 1 suggests that a number of spikes can credibly be mapped to an increase in the probability of adopting stricter carbon policies. For example, this includes the introduction of the CO2 tax in 2007M6, the "green wave" at the Federal election in 2019M10 or the government proposal of a new CO2 tax in 2022M9. In Additional file 1: Figure G.2, I further show that the CPR index is positively correlated to the Environmental Policy Stringency index from the OECD, thereby suggesting that the index is generally associated with a tightening of climate policies.

On the other hand, the approach also captures a number of events which appear to coincide with a weakening of existing climate policies. Examples include the election of Donald Trump or the rejection of the Swiss CO2 law in the ballot box. While these events likely generated uncertainty and risks regarding the transition towards a greener economy, and, as such, fit into the definition of climate-related policy risks, they may nevertheless not map directly with the definition of transition risk shocks from Fried et al. (2022).[3] In the next section, I leverage on the daily CPR index to manually identify a number of events that can be more directly interpreted as an increase in the probability of adopting stricter climate policies. I refer to these events as "transition risk events".

4.4 Identifying transition risk events

To identify transition risk events, I consider the daily version of the CPR index and identify local peaks in the index, that is days in which the share of articles containing keywords related to climate, policy and risk is higher than both the previous and the next day. For each local peak, I manually read all the retrieved climate-related articles and identify events which can reasonably be interpreted as an increase in the probability of adopting stricter policies. To qualify as a transition risk event, I further require that at least three different articles refer to the same event in a given day. This procedure ensures that each transition risk event received sufficient media coverage and fit into the definition of transition risk shocks from Fried et al. (2022). Using

[3] This being said, there is anecdotal evidence that such events are not always effectively interpreted as a loosening of existing policies by economic agents. For example, Holden (2019) argue that many large automakers such as Ford, Honda, Volkswagen or BMW decided to adopt stricter fuel economy standards than those proposed by the Trump administration, out of fear that "years of regulatory uncertainty [...] could end with judges deciding against Trump". Furthermore, around one year following the narrow rejection of the Swiss CO2 law (51.59% to 48.41%), the Federal Council proposed a new CO2 law, clearly stating that the climate objectives remained the same. More generally, even a weakening of climate policies today can increase transition risk. The reason is that delaying climate action today can lead to a more abrupt adoption of additional climate policies in the future, for example because inaction increases physical risk (Adrian et al. (2022)).

Table 1 Transition risk events

Date	Label	Type
2022-09-16	Switzerland sets out revised C02 law plan	Domestic
2022-04-04	New IPCC report	International
2021-10-30	G20 meets in Rome	International
2021-09-26	Bern voters approve constitutional amendment codifying climate neutrality by 2050	Domestic
2021-08-09	IPCC report warns of the rapid degradation of the planet	International
2021-07-14	European Commissions unveils its plan for CO2 reductions (fit-for-55 package)	International
2021-06-04	127 Nobel Prize winners call for climate actions	International
2021-05-31	FINMA specifies transparency obligations for climate risks	Domestic
2021-03-16	Federal Environment Office warns of climate change risks in Switzerland	Domestic
2020-12-11	EU agrees on tougher climate goals for 2030	International
2020-11-07	Election of Joe Biden	International
2020-01-04	A right-wing-Green coalition takes office in Austria	International
2019-10-20	"Green Wave" at the Swiss Federal Election	Domestic
2019-10-10	Report finds that climate change could have large costs for Swiss infrastructures	Domestic
2019-09-25	New alarming IPCC report	International
2019-08-16	A plane ticket tax is proposed by a state commission	Domestic
2019-06-22	FDP officially supports the Paris Climate Agreement	Domestic
2017-10-06	Switzerland ratifies the Paris Agreement	Both
2017-05-21	Swiss electorate accepts the revised Federal Energy Act	Domestic
2014-09-23	Federal Council pledges a minimum of 100 million to UN Green Fund	Domestic
2012-07-03	IEA's report on Switzerland highlights the necessity of a CO2 tax	Domestic
2010-01-21	The Federal Council proposes a new tax on high-polluting cars	Domestic
2007-04-20	Swiss Green party above 10% of vote intentions for the first time	Domestic
2007-03-12	A climate initiative to reduce CO2 emissions by 30% is proposed	Domestic
2007-02-07	The EU Commission aims to reduce the average CO2 emissions of new cars	International
2006-12-14	A 6 cent tax on fuel oil will be introduced to meet the Kyoto objectives	Domestic
2006-08-31	California pledges to reduce CO2 emissions by 25% by 2020	International
2006-06-21	National parliament confirms its willingness to introduce a CO2 tax	Domestic
2004-08-03	The Federal government opens discussions about various types of CO2 taxes	Domestic
2002-05-31	The EU ratifies the Kyoto Protocol	International
2001-05-29	Proposition to increase oil prices to finance public transport	Domestic
2001-03-19	Alarming IPCC report presented to the parliament	Both

This table displays the transition risk events identified using the daily CPR index. The procedure to find these events is as follows. First, I isolate "local peaks" which are defined as days where the share of CPR-related articles is higher than both the previous and the next day. This step ensures that the underlying event received important media coverage. Second, I read manually all retrieved articles and identify articles related to an event that can reasonably be interpreted as an increase in the probability of adopting tougher climate policies. Third, I require that at least three articles make reference to the same event for it to be considered as a "transition risk event"

this procedure, I identify 32 events, which relate to both domestic and international developments. The resulting events are displayed in Table 1. As we can see and consistent with the secular increase in the CPR index since 2019, a disproportionate share of transition risk events take place after 2019. However, a number of events also take place before, such as the acceptance by Swiss voters of the revised Federal Energy Act in 2017M5, or the ratification of the Kyoto Agreement by the European Union in 2002M5. More than half the of the events relate to domestic policies.

5 The macroeconomic effects of Climate Policy Risk

In this section, I test empirically the theoretical prediction of Fried et al. (2022) on the macroeconomic effect of climate transition risk. In their model, climate transition risk—defined as the probability that a carbon tax will be implemented in the next period—distorts the composition of capital and results in lower output today, even before the actual implementation of the carbon tax. The mechanism is that higher transition risk reduces the expected return of fossil capital relative to clean capital and shifts the economy towards cleaner production. This compositional shift reduces output because it is different from the optimal allocation without risk. Transition risk leads to a reduction in emissions, both because the economy produces less and because the remaining production is cleaner.

5.1 Econometric approach

To test the effect of CPR on output, I rely on a monthly VAR with four standard macroeconomic variables (real GDP ($RGDP_t$), an equity price index ($EQUITY_t$), CPI (CPI_t) and the policy rate (IR_t)) to which I add the CPR index (CPR_t) as well as the Swiss Economic Policy Uncertainty index (EPU_t) to ensure that the results are not driven by overall *economic* policy uncertainty. As a robustness exercise, I also consider the US Economic Policy Uncertainty index from Baker et al. (2016). Following Sims et al. (1990), the VAR is estimated in levels. With the exception of CPR_t, EPU_t and IR_t, all the other variables enter in log levels. The VAR is estimated with a constant term. The sample starts in 2000M1 and is restricted by the availability of the CPR index. Following the recommendation of Lenza and Primiceri (2020), I do not include the Covid-19 crisis and end the sample in 2020M2. Based on the AIC criterion, I consider a baseline with 3 lags. Defining $Y = [CPR_t, EPUt, RGDP_t, EQUITY_t, CPI_t, IR_t]'$, the VAR can be written as:

$$Y_t = C + \mathbf{\Phi}(L)Y_{t-1} + u_t \quad (1)$$

where C is a constant term, $\mathbf{\Phi}(L)$ is the lag matrix in companion form and u_t are the reduced form residuals. I further assume a linear mapping between structural shocks ε_t and the reduced form residuals, as defined by the impact matrix B: $u_t = B\varepsilon_t$

Identification of the impact matrix is achieved using a shock-based scheme à la Ludvigson et al. (2021) and narrative restrictions around the transition risk events identified in Table 1 which take place before the end of the sample in 2020M2. For these events, I require that the identified CPR shocks have contributed more than 20 per cent to the unexpected increase in the CPR index. In Additional file 1: Appendix D, I make sure that the results are not driven by the exact choice of the threshold by considering alternative values, namely 0 and 10 per cent. As in Berthold (2023), inference is conducted using an extension of the wild bootstrap procedure from Gonçalves and Kilian (2004). In the bootstrap procedure, I work with K=1 million rotational orthonormal matrices. Confidence intervals are obtained by targeting different percentiles over all selected models. In Additional file 1: Appendix E, I provide additional details about the identification strategy and the bootstrapping approach.

Given the lack of existing exogenous proxies for CPR, as well as the lack of clear theoretical restrictions regarding the timing of the shock, the flexibility offered by the shock-based identification scheme appears as being particularly valuable in this setting. This flexibility, however, generally comes at the cost of wider confidence intervals, as, for example, compared to the more traditional Cholesky identification scheme which I also consider.

5.2 Results

Figure 2 displays the dynamic response of the endogenous variables in the VAR to a narratively identified one standard deviation CPR shock. I find that CPR shocks are associated with a significant negative effect on real GDP, in line with the predictions from Fried et al. (2022). Quantitatively, a one standard deviation shock leads to a decline of around 0.1 per cent in real GDP after 6 months. CPR shocks lead to a significant increase in the Economic Policy Uncertainty index, suggesting that CPR can give rise to aggregate economic policy uncertainty.

In contrast to the theoretical predictions from Fried et al. (2022), I find no significant effect of CPR shocks on equity prices. In Additional file 1: Appendix C, I consider "green" and "brown" equity price indices, but do not find evidence in favour of heterogeneous responses (see Additional file 1: Figure C.6). In my view and as I will argue in Section 6, a potential explanation for this lack of result is that climate-related policy risks have only recently become a major source of concerns for investors (either because policies are becoming more stringent or receive more news coverage), and as such may not have been systematically included in asset prices until recently.

5.2.1 Robustness

I run a number of robustness checks in Additional file 1: Appendix C. Additional file 1: Figure C.1 shows that the negative response of output is not driven by the Great Financial Crisis period, as restricting the sample from 2010M1 to 2020M2 leads to a similar negative response of real GDP. I also consider alternative thresholds for the narrative restrictions (namely 0 and 10 per cent) in Additional file 1: Figure C.2 and find that it has virtually no effect on the median response, but generally lead to wider confidence intervals. Additional file 1: Figure C.5 considers the US Economic Policy Uncertainty index from Baker et al. (2016) instead of the Swiss Economic Policy Uncertainty index. Results remain broadly unchanged. Additional file 1: Figure C.3 re-estimates Eq. (1) using a Cholesky identification scheme ordering the CPR index first. Additional file 1: Figure C.4 also considers a Cholesky identification scheme, but orders the CPR second and the Economic Policy Uncertainty index first.

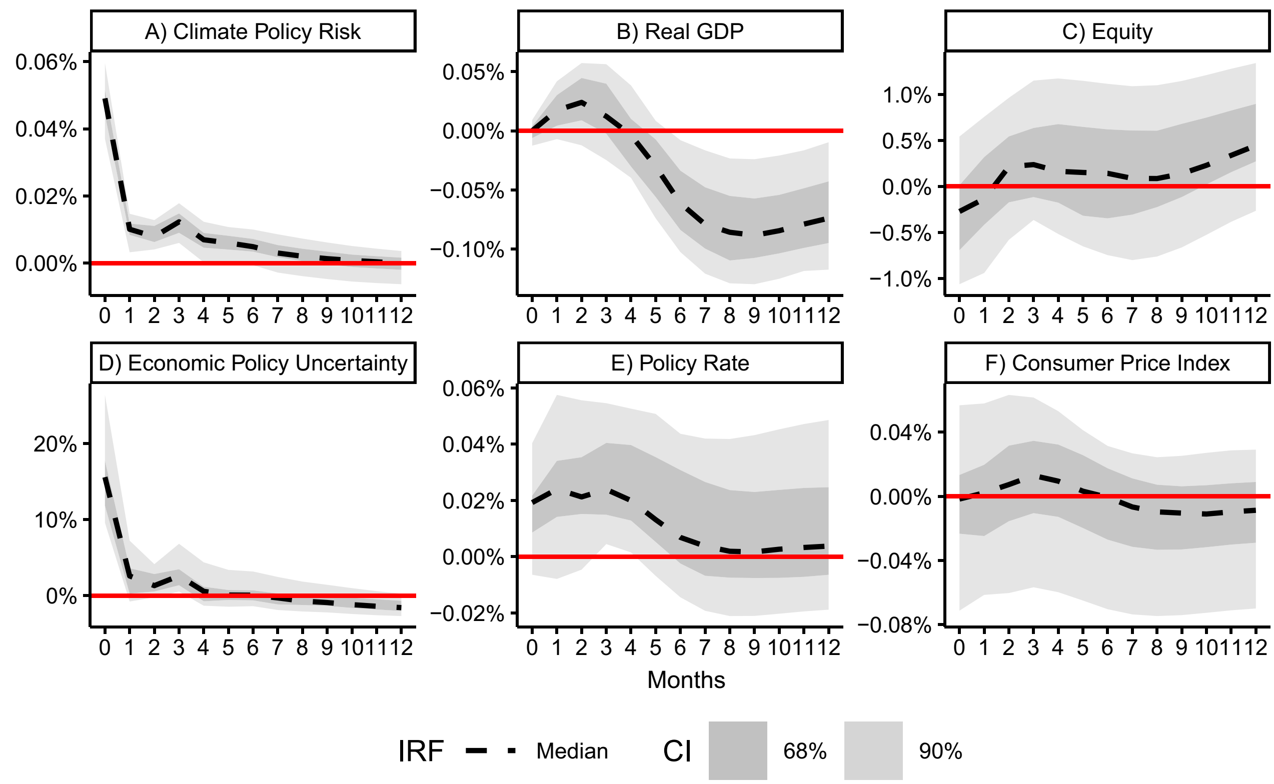

Fig. 2 Dynamic effects of a Climate Policy Risk shock. *Note*: Impulse response functions correspond to a one standard deviation shock to the reduced form residual of the CPR index variable. Shocks are set-identified using narrative restrictions around the transition risk events from Table 1 which take place before the end of the sample in 2020M2. Confidence intervals and median response are obtained using the extension of the wild bootstrap procedure (Additional file 1: Appendix E.3). I consider 1,000 bootstrap replications. The policy rate is expressed in per cent, and the Swiss Economic Policy Uncertainty index is normalized to have a mean equal to 100. All the other variables are in log levels

In both cases, the effect of CPR on real GDP is negative and even stronger than in the baseline regression at around −0.15 per cent. Overall, I conclude that the negative response of output to CPR shocks is robust and not driven by the exact sample choice, specification or the identification scheme.

5.3 Climate Policy Risk and CO2 emissions

Another theoretical prediction from Fried et al. (2022) is that an increase in climate transition risk reduces emissions today, even before the actual policy is implemented. This result is important because it runs counter to the prediction from the "green paradox" literature (e.g. Sinn (2008)) which argues that a higher risk of future climate regulation would drive up current emissions by increasing the incentives to extract fossil fuel. In the VAR specification, I am not able to directly test this prediction because measures of CO2 emissions in Switzerland are only available at the yearly frequency.

However, I propose two types of indirect evidence to better understand the relationship between CPR and CO2 emissions. Panel A) of Figure 3 plots the correlation between yearly growth in GDP and CO2 emissions. As we can see, the relationship is positive. This suggests that the negative response of output following CPR shocks that I find generally coincides with lower CO2 emissions, as predicted in Fried et al. (2022). Panel B) plots the correlation between yearly growth in the CPR index and the subsequent average yearly growth of CO2 emissions at the firm level. Similarly, a higher CPR is generally associated with lower subsequent CO2 growth. Overall, I interpret this as suggestive evidence that CPR shocks lead to lower CO2 emissions.

6 The financial effects of Climate Policy Risk

In this section, I investigate the asset pricing implications of the CPR index for publicly listed firms in Switzerland,[4] and investigate whether they are in line with theoretical literature such as Fried et al. (2022) and Pastor et al. (2021). Fried et al. (2022) find than an increase in climate

[4] Given that the CPR index also covers domestic developments, I postulate that firms that are headquartered in Switzerland are likely to be the most affected by variations in the index.

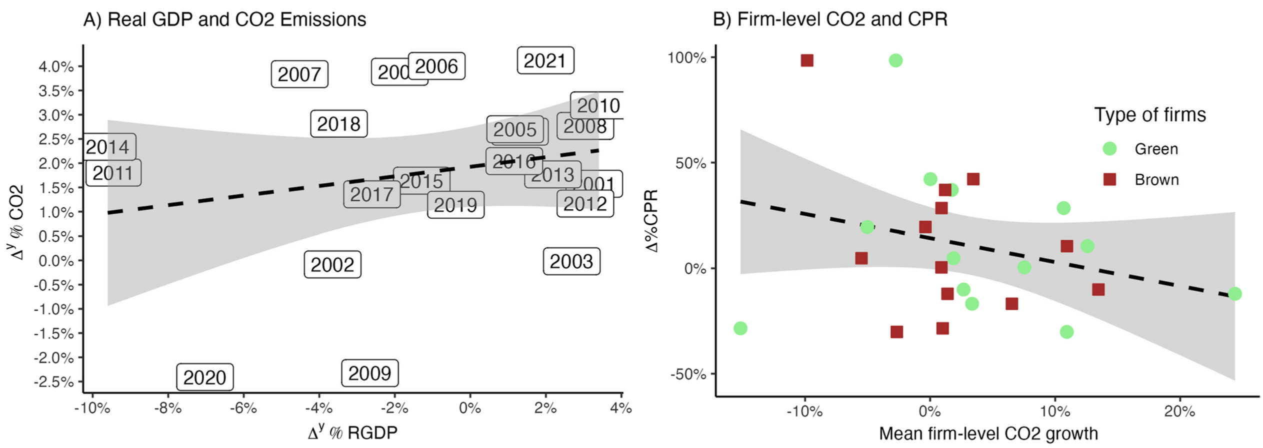

Fig. 3 Firm-level CO2 emissions and Climate Policy Risk yearly growth. *Note*: **A** of this figure compares yearly growth in CO2 and RGDP. CO2 data is from OurWorldInData. **B** plots the relationship between yearly changes in the CPR index and subsequent (one-year ahead) firm-level average growth in CO2 emissions. Average firm-level growth in CO2 emissions is obtained by averaging across all firms which disclose their CO2 emissions in a given year

transition risk disproportionately reduces the expected returns of brown capital. In Pastor et al. (2021), green assets can outperform brown ones when concerns about climate change rise unexpectedly. This results from a change in customers' and regulators' preferences for sustainability that leads to a downward revision of expected cash flows of brown firms. I postulate that variations in the CPR index can be interpreted as changes in sustainability preferences. The underlying argument is that, as the CPR index rises, policymakers are more likely to implement regulation that would disproportionately harm brown firms.

6.1 Multivariate factor analysis

As in Ardia et al. (2022), I first consider a multivariate panel linear regression to test whether an unexpected increase in the CPR index (denoted as ΔCPR_t) affects heterogeneously green and brown firms. The underlying argument is that, if CPR is priced, the GMB portfolio should rise in value when CPR increases, as green firms are expected to fare better than browner ones. To look at this, I regress the monthly returns of a green minus brown (GMB) portfolio (denoted by r_t^{GMB}) on ΔCPR_t and a set of standard risk factors F_t using OLS:

$$r_t^{GMB} = \alpha + \beta_{CPR} \Delta CPR_t + \Gamma F_t + e_t \quad (2)$$

where α is a constant, β_{CPR} and Γ are regression coefficients and e_t is an error term. I define ΔCPR_t as the residual from an autoregressive process on the CPR index. For F_t, I follow standard factor models and consider four main factors, namely size, value, momentum and the market, following Ammann and Steiner (2008) who showed their relevance in the Swiss market. Additional file 1: Appendix F provides details about their construction. The sample covers the period 2000M4 to 2022M11. In light of the results from Fried et al. (2022) and Pastor et al. (2021), we expect β_{CPR} to be positive, that is, green stocks outperform brown ones when CPR increases unexpectedly. Intuitively, a positive β_{CPR} means that the GMB portfolio yields higher returns when CPR rises unexpectedly, which implies that it behaves as a hedge. An insignificant β_{CPR} implies that CPR is not priced.

6.1.1 The GMB portfolio

To build the GMB portfolio, we need to define what is considered as a green firm. In contrast to Engle et al. (2020) who rely on proprietary ESG scores, I decide to rely on CO2 emissions only. This is motivated in part because CO2 data are more easily available and also because CO2 emissions map more directly to the definition of green and brown capital considered in Fried et al. (2022). Furthermore, Bolton and Kacperczyk (2021a) and Ardia et al. (2022) also consider firms' CO2 emissions in their analyses. On the other hand, ESG scores have advantages, but are also subject to a number of limitations (see, for example, Pagano et al. (2018) for a discussion).

To measure CO2 emissions, I rely on the sum of scope 1 and scope 2 emissions. I consider two definitions of the brown dummy variable. In the first—which we refer to as the *relative* brown dummy—a firm is defined as brown if its CO2 emissions are above the median within a given sector, and green otherwise. This definition ensures that the distribution of sectors for brown and green firms remains comparable. We refer to the resulting portfolio as the *sector-diversified* GMB portfolio. The second specification, referred to as the *absolute* brown dummy, labels a firm as brown if its CO2 emissions are above the median across all firms. As a result, brown firms are likely to be tilted towards sectors with relatively high emissions. We refer to this portfolio as the *non-sector-diversified* GMB portfolio. For each dummy specification, I construct the green (brown) portfolio only considering firms with the brown dummy equal to zero (one). I then rank firms from the highest to the lowest polluting and use this ranking to define the weights of each firm in the green and brown portfolio.[5] As a robustness check, I ensure that the results presented in this paper are robust to an equal weighting scheme. The GMB portfolio is obtained by going long in the green portfolio and shorting the brown one. Letting Z^i_{t-1} be a weight vector and r_t^i the vector of monthly returns for firms of type $i \in \{Green, Brown\}$, we obtain the GMB portfolio according to:

$$r_t^{GMB} = Z^G_{t-1} r^G_t - Z^B_{t-1} r^B_t \tag{3}$$

where $Z^G_{t-1} r^G_t$ and $Z^B_{t-1} r^B_t$ can be interpreted as the (weighted) returns of the green and brown portfolios, respectively.

6.1.2 Results

According to the SVAR exercise in Section 5, CPR shocks do not appear to have an heterogeneous effect on brown versus green firms over the whole sample, which runs counter to the predictions from Fried et al. (2022) and Pastor et al. (2021). However, a potential explanation is that widely shared concern about climate change is a relatively recent phenomenon and that investors may have only recently started to systematically incorporate these concerns into asset prices. As a result, the sample spanning the period 2000M1 to 2020M2 may blur some of the more recent developments.

To shed light on the potential time series property of the relationship between CPR and asset prices, I estimate equation (2) using a rolling 10-year window and report the resulting estimated coefficient $\hat{\beta}_{CPR}$ over time, along with its 90th percentile. I report the resulting coefficients and their confidence intervals at the end of each estimation sample, such that a coefficient at a given date is actually estimated with data spanning the previous ten years. Figure 4 reports these coefficients using the sector-diversified specification of the GMB portfolio.

As we can see, the estimated coefficient $\hat{\beta}_{CPR}$ is not statistically significant for most of the sample. In other words, the performance of the GMB portfolio is largely independent of the CPR factor. Since 2022, however, the coefficient turns significantly positive. This implies that, when considering data from 2012 (i.e. 10 years before 2022) onwards, a sector-diversified GMB portfolio indeed tends to provide significantly higher returns when CPR rises unexpectedly, in line with predictions from Pastor et al. (2021). This suggests that CPR is increasingly reflected in asset prices in Switzerland.

According to the results, CPR has negative macroeconomic effects and is increasingly reflected in asset prices. In this context, it may be particularly relevant for investors to develop strategies to hedge this type of risk. In Additional file 1: Appendix H, I investigate the hedging properties of the two GMB portfolios in real time (and out of sample) following the portfolio mimicking approach from Engle et al. (2020). I find that the sector-diversified GMB portfolio is a good real-time hedge to unexpected increases in the CPR index, while the non-sector-diversified GMB portfolio does not offer hedging properties.

6.1.3 Robustness

Additional file 1: Figure D.1 of Appendix D displays a number of robustness checks of Figure 4. In Panel A), I re-estimate the rolling regressions by defining the brown dummy variable using scope 1 emissions only (instead of the sum of scope 1 and 2 as in the baseline). Similarly, Panel B) defines the brown dummy variable considering scope 2 emissions only. In Panel C), I consider an equal weighting scheme (rather than CO2-based weights as in the baseline). Results turn out to be remarkably robust to these three choices. In Panel D), I rerun equation (2) but consider the non-sector-diversified GMB portfolio returns as the dependent variable. According to the results, the coefficient in the more recent period is not statistically different than zero. This suggests that the sector-diversified GMB portfolio provides stronger hedging properties to CPR shocks than the non-sector-diversified portfolio. This is confirmed in Additional file 1: Appendix H. Taken at face value, this could suggest that investors care in priority about within-sector CO2 emissions, rather than absolute CO2 emissions (irrespective of the sector). I leave a more careful investigation of this question for future research.

6.2 Event-study approach

To complement the previous results, I adopt an event-study approach combined with local projections to investigate the dynamics of brown versus green firms around the transition risk events displayed in Table 1. These events appear particularly suited because they can arguably be interpreted as an increase in the probability of adopting stricter climate policies, which maps directly

[5] In more detail: green (brown) firms with the lowest (highest) CO2 emissions get the largest weights in the green (brown) portfolio.

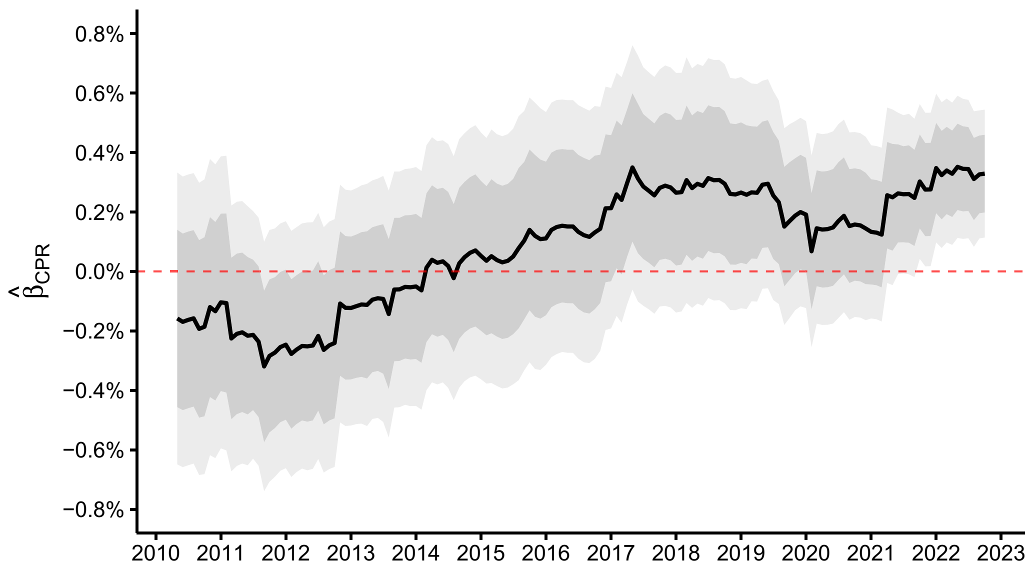

Fig. 4 Evidence from rolling panel linear regressions. *Note*: This figure plots the estimated coefficient $\hat{\beta}_{CPR}$ from running a rolling regression of Eq. (2) using the sector-diversified specification of the GMB portfolio over a sample covering the 10 previous years. The coefficient in *t* is thus estimated using a sample covering the period {*t* minus 10 years, *t*}. The standard errors are estimated using the HAC estimator. The confidence intervals are obtained by adding 1, respectively, 1.645 standard error

with the definition of climate policy transition risk considered in Fried et al. (2022).

6.2.1 Econometric approach

For the event-study, I follow the approach from Berthold et al. (2023) which is inspired by Ottonello and Winberry (2020) and relies on Jordà (2005)-type local projection methods. Let $p_{i,t}$ be the log equity price of firm i in t and $\Delta p_{i,t+h} = p_{i,t+h} - p_{i,t-1}$ be the percentage price change at horizon $t+h$ (in days or months depending on the specification) relative to the price in $t-1$. We further define $I\{Event\}_t$ as a dummy taking the value 1 when a transition risk event from Table 1 takes place. Consistent with the sector-diversified specification of the GMB portfolio, we define $Brown_{i,t}$ as a within-sector brown dummy that takes the value 1 if a firm's CO2 emissions are above the median within a given sector. Finally, let $X_{i,t}$ be a vector of firm-level controls (sales growth, total assets, price-to-book value and debt-to-assets ratio). I estimate the following local projection regression for $h = 1,...,12$:

$$\Delta p_{i,t+h} = \alpha_i + \alpha_{h,s} + \beta_h \left(I\{\text{Event}\}_t \times Brown_{i,t} \right) + \Gamma X_{i,t} + u_{i,t+h} \tag{4}$$

On top of firm-level controls $X_{i,t}$, I control for firm fixed-effect (α_i) to capture permanent differences across firms. I further add a double interacted fixed-effect ($\alpha_{h,s}$ with horizon (h) and sector (s)) to control for any sector characteristics that may affect the firm price response over time. The coefficient of interest β_h captures the differing response in the variation of stock price at horizon h between a brown and a green firm in a given sector. A negative β_h indicates that brown firms see their stock prices react more negatively (either increase less or decrease more) than their greener counterparts, following a transition risk event.

6.2.2 Results

Figure 5 plots the results. 68 and 90% confidence bands are obtained by conservatively clustering standard errors in two ways (firm and event date level). Panel A) depicts the differing behaviour of brown versus green firms following a transition risk event at the daily frequency. As we can see, the coefficient is negative and statistically significant at the 90% confidence interval a few day days after the event. Quantitatively, the drop in stock price is around 0.6% larger for brown firms. Panel B) plots the same regression but at the monthly frequency. As we can see, the negative coefficient at the 12-month horizon suggests that the stock price of brown firms tend to react more negatively than greener firms and that this effect is persistent. Quantitatively, a brown firm sees its stock price decrease by roughly 3–4% more 12 months after the event. Overall, the results confirm the relevance of transition risk for the dynamics of stock prices, in both the short and longer run and are in line with Fried et al. (2022) and Pastor et al. (2021).

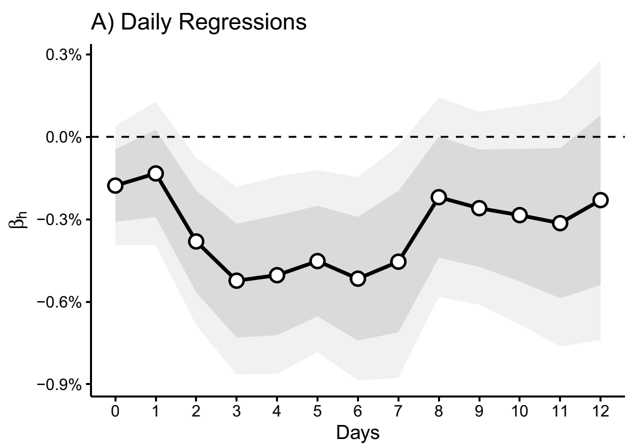

Fig. 5 Event study: transition risk events. *Note*: This figure plots the coefficient β_h from Eq. (4) for $h = 1,\ldots,12$. **A** estimates the equation using daily stock prices, while **B** uses monthly stock prices. Standard errors are clustered in two ways at the date and firm level. Confidence bands display the 68 and 90% intervals, respectively

6.2.3 Robustness

Additional file 1: Figure D.2 in Appendix D displays a number of robustness checks. In particular, I rerun the regressions only considering *domestic* transition risk events. I also run robustness checks using only scope 1 or scope 2 to define the brown dummy variable (instead of the sum of scope 1 and 2 as in the baseline). In Additional file 1: Figure D.3, I also consider the absolute brown dummy specification (instead of the relative brown dummy specification as in the baseline). Results turn out to be robust to these different choices.

7 Conclusion

This paper develops a new Climate Policy Risk (CPR) index and leverages on narratively identified transition risk events to identify and quantify the macroeconomic and financial effects of CPR. At the macroeconomic level, I find that CPR shocks lead to a significant drop in output and are associated with lower firm-level emissions. Using firm-level equity price data, I document that a sector-balanced portfolio that goes long (short) in firms with low (high) within-sector CO2 emissions is an increasingly good hedge to unexpected increases in climate-related policy risks. I further show the relevance of transition risk events for the dynamics of asset prices using an event-study approach combined with Jordà (2005)-type local projections.

Overall, the results highlight the (increasing) macrofinancial importance of CPR and are in line with theoretical contributions such as Fried et al. (2022) and Pastor et al. (2021). I see work on empirically documenting the macroeconomic channels of adjustment to transition risk as being fruitful venues for future research.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41937-024-00122-5.

Additional file 1. Online Appendix.

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The author read and approved the manuscript.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
No competing interests to disclose.

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