Predictability of Economic Slowdowns in Advanced Countries over Eight Centuries: The Role of Climate Risks[#]

Abstract

We analyze the predictive content of climate risks, proxied by change in global temperature anomaly and its volatility, on a dummy variable capturing periods of zero and negative growth rates of eight industrialized countries. In this regard, we apply a Probit model to longest possible historical datasets available for these countries covering 1311 till 2020, and control for inflation and interest rates. We find strong evidence that changes in global temperature anomaly and/or its stochastic volatility in particular, tend to predict slowdown or stagnation in all the eight economies at the different predictive horizons considered.

Keywords: Growth; Climate Risks; Probit Model; Predictions

JEL Codes: C25, C53, O40, Q54

1. Introduction

Climate change is undoubtedly the most defining of the existing challenges that we as human beings face in the current era, with it impacting the health and wellbeing of every person on the planet by posing a large aggregate risk to the economy (Giglio et al., 2021). In this regard, a growing number of studies have provided, primarily post World War II data-based,[1] empirical evidence that climate risks, as proxied via growth in temperature and its volatility, tend to adversely impact economic growth (see, Sheng et al. (2022a, b), Huber et al. (forthcoming), and Kim et al. (forthcoming) for detailed reviews of this literature). Note that, the underlying theoretical frameworks associated with the empirical research, develop models wherein climate risks tend to undermine economic growth via negatively impacting not only labour productivity and capital quality, but also through the patent obsolescence channel (which dampens research and

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[1] Donadelli et al. (2021) provided a Vector Autoregressive (VAR) model-based structural analysis of the negative influence of country-specific temperature volatility on measures of economic activity (including growth) of the United Kingdom over the period of 1900 to 2015.

development (R&D) expenditure growth). In other words, climate risks can impact growth from both the demand- and supply-side of the economy.

Against this backdrop, the objective of this paper is to analyze the role of the changes in global temperature anomaly and its volatility in predicting the probability of non-positive economic growth of eight advanced economies (France, Germany, Holland, Italy, Japan, Spain, the United Kingdom (UK), and the United States (US)) covering eight centuries of annual data, based on a Probit model. Specifically speaking, the data samples for France, Germany, Holland, Italy, Japan, Spain, the UK, and the US start at 1388, 1327, 1401, 1311, 1871, 1419, 1311, and 1787 respectively, with all of them ending in 2020. While estimating the time series Probit model for each of the countries to analyze the role of changes in global temperature anomaly and its volatility, we also control for country-specific inflation and interest rates.

Note that the choice of these countries is purely due to the availability of long-span data, and for the fact that they cover on average 78% of Gross Domestic Product (GDP) of the advanced economies (Schmelzing, 2018, 2020). We consider the usage of historical data to be particularly important in tracking the evolution of the role of slow, but steady, long-term climate risks on economic growth. The usage of the longest possible dataset for capturing the impact of climate risks on the future path of slowdown in economic growth allows us to avoid the issue of sample selection bias. Besides this, the decision to investigate these eight industrialized economies is motivated by the origin of the Industrial Revolution, primarily in the UK, Europe and the US, which in turn can be considered to be the starting point of climate change.

To the best of our knowledge, this is the first paper to predict the slowdown of economic growth of eight advanced countries due to issues of climate risks by using over 700 years of data. Moreover, besides the empirical relevance of our work, predicting recessionary effects of global changes in temperature anomaly and its volatility on economic growth for the major industrialized economies, also has important climate change-related policy implications for not only these economies under consideration, but the global economy in general, given the high degree of connectedness of countries in the modern day.

The remainder of the paper is organized as follows: Section 2 outlines the data and the methodology, while Section 3 presents the empirical results, and Section 4 concludes.

2. Methodology and Data

We estimate the following Probit model:

$$\Pr(D_t = 1|X_t) = \Phi(\beta_0 + \beta_1 D_{t-1} + \beta_2 CTA_{t-h} + \beta_3 SVCTA_{t-h} + \beta_4 INFL_{t-h} + \beta_5 IR_{t-h}) \quad (1)$$

with h = 0, 1, 2, 5 and 10, to capture contemporaneous, short-, medium-, and long-run predictability respectively. Pr is the probability, and Φ is the cumulative distribution function. The dummy variable D_t, capture periods associated with non-positive (i.e., both zero and negative values) of economic growth, and X_t includes to the various predictors. In this regard, consistent with the theory outlined in the introduction, *CTA* corresponds to the change (first-difference) of global temperature anomaly; *SVCTA* is the stochastic volatility of *CTA*, which is obtained by estimating the stochastic volatility model in Kastner and Früwirth-Schnatter (2014), which in turn is a preferred approach in the climate-change literature for capturing second-moments of temperature changes and/or growth (Alessandri and Mumtaz, 2021), with these two variables serving as theoretically consistent proxies of climate-related risks; *INFL* is the inflation rate, and; *IR* is the nominal interest rate. The lag of D_t as a predictor is used to control for persistence of the dependent variable. The model is estimated using maximum likelihood to determine whether the predictors, and *CTA* and *SVCTA* in particular, increase the probability of economic slowdown.

As far as the underlying data is concerned, real GDP in millions of 1990 International Geary-Khamis dollars for the eight countries are derived from the work of Schmelzing (2020) till 2018,[2] and then updated to 2020 using the data from the World Development Indicators (WDI) of the World Bank[3], which we convert into annual growth-rates to generate D_t. The associated annual inflation and nominal interest rate (bond yield) are also derived from the same two sources used for the real GDP. Since country-specific temperature data is not available for the entire period of analysis, i.e., 1311-2020, but as is well-known countries around the world tend to depict similar positive trends in temperature (Hansen et al., 2010), risks of climate change, or more specifically, global warming in this regard, is based on global temperature anomaly (in degree Celsius) with respect to the May-April annual average over 1961-1990. The temperature anomaly data till 2019 (starting from 1 AD) is obtained from Hawkins (2020),[4] and then updated for the year 2020 from the National Oceanic and Atmospheric Administration (NOAA).[5] We then take the first-difference of temperature anomaly to obtain *CTA*, and estimate the SV model on this data to derive *SVCTA*, i.e., to capture the first- and second-moment risks associated with global warming on historical economic slowdown of eight advanced countries.

[2] The data is available for download from: https://www.bankofengland.co.uk/working-paper/2020/eight-centuries-of-global-real-interest-rates-r-g-and-the-suprasecular-decline-1311-2018.
[3] This data is available in US dollars, which has an implied purchasing power parity (PPP) conversion rate of 1 with the International Geary-Khamis dollars.
[4] https://web.archive.org/web/20200202220240/https://www.climate-lab-book.ac.uk/2020/2019-years/.
[5] https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series.

3. Empirical results

The results from the time series estimation of the Probit model for each country at h = 0, 1, 2, 5 and 10, have been presented in five panels (for each of the h) in Table 1. As can be seen, probability of being in an economic slowdown or stagnation tends to get carried over from the last period, as captured by a positive and statistically significant β_1, particularly for all countries, barring Japan, and Spain, though weak evidence (at the 10% level of significance) is detected for the latter at h = 10. As far as the effect of *CTA* is concerned, the associated coefficient of β_2, is positive and statistically significant at the 10% level for Italy at h = 0, and Germany and the US at h = 2. Stronger impact at 5% level of significance for Germany due to *CTA* is detected at the medium-run, i.e., h = 5, with the effect on Japan also showing significance at the 10% level at this horizon. Interestingly, CTA weakly reduces the probability of Italy being in a slowdown or stagnation at the long-run, i.e., h = 10. Turning now to β_3, i.e., the coefficient corresponding to *SVCTA*, capturing adverse second-moment effects of global climate-change, i.e., volatility, we find that, compared to *CTA*, the effects are more widespread in terms of countries, the forecast horizon, and statistical significance. Specifically speaking, at h = 0, β_3 is positive and statistically significant at the 5% level for France, Holland, Spain and the UK, and at the 10% level for Japan. A similar observation holds at h = 1, though now for UK, the effect is positive and statistically significant at the 1% level. At h = 2, 5 and 10, Germany replaces Japan for these set of countries showing statistical significance contemporaneously and under the one-year-ahead case. As with Japan, likelihood of slowdown and stagnation in Germany too is weakly impacted at the 10% level by *SVCTA*. The effect on France, Holland, Spain and the UK continues to be positively significant at least at the 5% level at the short, medium- and long-runs, with strong significance at the 1% level derived for France at h = 5, and Holland at h = 10, and the UK at h = 2 and 10. Finally, as far as interest rate and inflation are concerned, the former is more likely to cause non-positive growth rates, particularly for France, Holland, Italy and the UK, with the effect of inflation being primarily statistically insignificant.[6] Note that, since all the four predictors have been standardized by dividing with their sample standard deviation, we additionally observe that, when significant, the two strongest predictors are stochastic volatility of the change in global temperature anomaly, and the interest rate.

In sum, we provide strong evidence of the importance of climate risks, as captured by changes in global temperature anomaly and its associated volatility, in predicting the slowdown or stagnation of historical economic growth in the eight major advanced economies.[7] And this is particularly the case associated with the second moment effects of global climate change, i.e., volatility, for the European countries (especially, France, Holland and Spain) and the UK, where the Industrial Revolution kicked-off relatively earlier in comparison to Japan and the US.

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[6] Interestingly for Japan, higher interest rates tend to consistently reduce the probability of zero or negative economic growth, and can be possibly associated with historically low-levels of interest rates witnessed in the country. Hence, an increase in interest rates from exceptionally low-levels could boost saving and growth. At the same time, the negative coefficient associated with inflation for France, Spain, the UK and the US, (and weakly for Germany) at certain horizons, could be indicative of the well-established nonlinear relationship between growth and inflation, with the effect only being negative beyond a certain threshold of inflation ranging between 2.5% to 3% (Omay and Öznur Kan, 2010), which is, in general, higher than the average inflation rate for the eight countries in our sample.

[7] Results from a Logit model, which are available upon request from the authors and have been suppressed to save space, yielded similar conclusions. We, however, prefer to rely on the findings from the Probit model since it is the widely-used framework when predicting economic slowdown. The reason behind this is that the logit is used to model the odds of success of an event as a function of independent variables, while the Probit is used to determine the likelihood that an item or event will fall into one of a range of categories, in our case negative or zero growth rate versus positive ones, by estimating the probability that observation with specific features will belong to a particular category.

Table 1: Probit model results of predictability

Panel A: $h = 0$								
	France	**Germany**	**Holland**	**Italy**	**Japan**	**Spain**	**UK**	**US**
β_0	-2.072***	-1.924***	-2.597***	-2.158***	-4.293*	-3.395***	-2.941***	-1.127**
β_1	0.874***	0.906***	0.985***	1.169***	-0.058	0.070	0.919***	0.358***
β_2	0.007	0.035	0.064	0.128*	0.081	0.038	-0.022	0.016
β_3	0.200**	0.091	0.196**	0.023	1.208*	0.877***	0.379***	0.085
β_4	-0.146**	0.041	-0.036	0.011	-0.195	-0.008	-0.149*	-0.248**
β_5	0.231***	-0.003	0.388***	0.277***	-0.417**	-0.254	0.859***	-0.118
Panel B: $h = 1$								
	France	**Germany**	**Holland**	**Italy**	**Japan**	**Spain**	**UK**	**US**
β_0	-2.058***	-2.007***	-2.600***	-2.223***	-4.278*	-3.473***	-2.831***	-0.897**
β_1	0.866***	0.926***	0.977***	1.158***	-0.091	0.083	0.947***	0.353***
β_2	0.016	-0.107	-0.023	-0.086	0.082	-0.062	0.045	-0.028
β_3	0.178**	0.115	0.201**	0.029	1.216*	0.892***	0.324***	0.020
β_4	-0.011	-0.146*	-0.042	0.015	-0.016	-0.174	0.085	0.011
β_5	0.236***	0.018	0.389***	0.309***	-0.443**	-0.162	0.789***	-0.179
Panel C: $h = 2$								
	France	**Germany**	**Holland**	**Italy**	**Japan**	**Spain**	**UK**	**US**
β_0	-2.076***	-2.256***	-2.573***	-2.131***	-3.524	-3.301***	-2.842***	-0.834*
β_1	0.865***	0.912***	0.973***	1.161***	-0.062	0.081	0.937***	0.354***
β_2	0.028	0.122*	0.016	0.012	-0.072	0.099	0.004	0.138*
β_3	0.186**	0.135*	0.191**	0.036	0.989	0.858***	0.352***	0.019
β_4	-0.043	-0.049	-0.012	-0.059	0.129	-0.101	-0.097	-0.067
β_5	0.241***	0.099	0.381***	0.265***	-0.459**	-0.269	0.794***	-0.217
Panel D: $h = 5$								
	France	**Germany**	**Holland**	**Italy**	**Japan**	**Spain**	**UK**	**US**
β_0	-2.117***	-2.256***	-2.613***	-2.171***	-2.442	-3.288***	-2.926***	-0.403
β_1	0.859***	0.927***	0.970***	1.171***	-0.044	0.068	0.965***	0.337***
β_2	-0.056	0.159**	-0.028	-0.106	0.158*	-0.040	-0.055	0.052
β_3	0.202***	0.137*	0.205**	0.034	0.598	0.871***	0.378***	-0.039
β_4	-0.081	-0.152*	-0.074	-0.082	-0.048	-0.302**	-0.177**	0.026
β_5	0.251***	0.097	0.391***	0.285***	-0.311*	-0.221	0.830***	-0.378**
Panel E: $h = 10$								
	France	**Germany**	**Holland**	**Italy**	**Japan**	**Spain**	**UK**	**US**
β_0	-2.113***	-2.341***	-2.719***	-2.209***	-1.903	-3.421***	-2.833***	-0.993**
β_1	0.848***	0.898***	0.951***	1.172***	-0.055	0.102*	0.947***	0.346***
β_2	-0.099	-0.018	-0.101	-0.134*	-0.042	-0.036	-0.114	-0.085

$\boldsymbol{\beta_3}$	0.196**	0.146*	0.223***	0.032	0.479	0.779***	0.337***	0.033
$\boldsymbol{\beta_4}$	-0.023	-0.043	-0.052	-0.058	-0.091	0.037	-0.004	-0.159
$\boldsymbol{\beta_5}$	0.249***	0.133	0.427***	0.305***	-0.354**	0.065	0.800***	-0.100

Note: The estimated Probit model is as follows: $\Pr(D_t = 1|X_t) = \Phi(\beta_0 + \beta_1 D_{t-1} + \beta_2 CTA_{t-h} + \beta_3 SVCTA_{t-h} + \beta_4 INFL_{t-h} + \beta_5 IR_{t-h})$ where, Pr is the probability; Φ is the cumulative distribution function; the dummy variable D_t capture periods associated with non-positive (i.e., both zero and negative values) of economic growth; *CTA* corresponds to the change (first-difference) of global temperature anomaly; $SVCTA$ is the stochastic volatility of CTA; *INFL* is the inflation rate; *IR* is the nominal interest rate. ***, **, and * indicates statistical significance at 1%, 5% and 10% levels, respectively. Sample periods for each country are as follows: France: 1388-2020; Germany: 1327-2020; Holland: 1401-2020; Italy: 1311-2020; Japan: 1871-2020; Spain: 1419-2020; the UK: 1311-2020, and; the US: 1787-2020.

4. Concluding remarks

We analyze the predictive content of climate risks, proxied by change in global temperature anomaly and its stochastic volatility, on periods of non-positive, i.e., zero and negative, growth rates, captured by a dummy variable in a Probit model, of eight industrialized countries. In this regard, we utilize the longest possible historical data available for France, Germany, Holland, Italy, Japan, Spain, the UK and the US till 2020, starting in 1388, 1327, 1401, 1311, 1871, 1419, 1311, and 1787 respectively. After controlling for inflation and interest rates, besides the persistence of the dummy variable itself, and considering contemporaneous and lagged (1-, 2-, 5-, and 10-year) predictive horizons, we find strong evidence that changes in global temperature anomaly and/or its volatility, tend to predict slowdown or stagnation in all the eight economies under consideration across at least one of the five predictive horizons considered. Moreover, compared to the first moment of climate change, the second moment tends to have a stronger impact, especially in France, Holland, Spain, and the UK, in line with the early origination of the Industrial Revolution in these countries.

Though we work with global temperature, the fact that the advanced economies have historically contributed the most to global warming and climate change, we can draw general policy conclusions from our findings. In particular, the main agenda of major industrialized countries should center around the development and implementation of green policies targeted towards reduction of the negative effects of variability in climate change. In this regard, more emphasis should be given to short-run policies, such as access to advanced after-treatment technology and rapid transition to renewable energy (Liu et al., 2019), instead of long-run ones, in reducing the adverse impact of annual temperature volatility.

As far as academics are concerned, our findings related to the observation that climate risks can lead to growth slowdown now provides an additional variable to consider when predicting historical recessions over and above the wide array of macroeconomic and financial predictors considered in this literature. Finally, with recent studies indicating the linkage between climate risks and financial assets (see, for example, Lee et al. (2022), Chen et al. (2023), Liu et al. (2023), and references cited there in), the fact that climate risks will cause growth to stall, which will cause conventional asset prices to fall and associated risk premia to rise, investors must consider sustainable green assets in their portfolios that can act as safe haven and hedge such risks (Cepni et al., 2022, Din et al., 2022).

In this paper, our analysis is limited to in-sample predictability, as part of future research, we can investigate out-of-sample forecasting, not only in the current time series context of the probit model, but also in a panel set-up, to increase the reliability of our findings based on pooled information. At the same time, the role of climate risks on defining global networks of the growth rates can also be analyzed using innovative methods recently outlined in Wu et al. (2022).

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