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Abstract: Many companies are setting ambitious targets to reduce their greenhouse gas emissions (GHG) per the Paris Agreement. However, there is limited evidence on the market effects of setting those targets. Using a GARCH model with a trend developed by the authors and a panel fixed effects model, this paper analyzes the short-run effects of committing and setting GHG targets on public companies' stock price returns and volatility. We find no evidence that committing or setting a target yields higher returns but contributes to a reduction in price volatility, albeit the impact is short-lived. In view of these results, we conclude that there are no visible stock market gains in the short term for companies that commit and set GHG targets and that other factors may explain their motivations to engage in GHG mitigation actions.
Keywords: Stock returns, Volatility, GHG emissions, ESG, GARCH
JEL Classification: C1, E1, I0, 04

Resumen: Muchas empresas están estableciendo objetivos ambiciosos para reducir sus emisiones de gases de efecto invernadero (GEI) según el Acuerdo de París. Sin embargo, hay pruebas limitadas sobre los efectos de mercado que tendría el establecimiento de esos objetivos. Utilizando un modelo GARCH con tendencia desarrollado por los autores y un modelo de panel de efectos fijos, este artículo analiza los efectos de corto plazo de comprometerse y establecer objetivos de GEI en el rendimiento y la volatilidad de los precios de las acciones de las empresas públicas. No se encuentra evidencia de que comprometerse o establecer un objetivo genere mayores retornos, pero si contribuye a reducir la volatilidad de los precios de las acciones, si bien el impacto es de corta duración. En vista de estos resultados, se concluye que no hay ganancias visibles en el mercado de valores en el corto plazo para las empresas que se comprometen y establecen objetivos de GEI y que otros factores pueden explicar sus motivaciones para participar en acciones de mitigación de emisiones.
Palabras Clave: Rendimientos accionarios, Volatilidad, Emisiones de GEI, ASG, GARCH

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1 Introduction

In 2015, 195 states and the European Union adopted the Paris Agreement, the most ambitious international treaty that aims to limit global warming to below 2 degrees Celsius and preferably at 1.5 degrees. The Intergovernmental Panel on Climate Change (IPCC) reports that human-induced greenhouse gas (GHG) emissions have caused an increase of 1.1°C above pre-industrial levels, causing negative and large impacts on a wide range of sectors, including agriculture, health, cities, and infrastructure, particularly damaging vulnerable populations (IPCC, 2022). Achieving the Paris Agreement goal will require rapid and strong efforts to cut GHG emissions in most sectors (IPCC, 2022). China, the United States, and the European Union have already committed to achieving net zero emissions by 2050. Since the launch of this Agreement, more than three thousand companies have adopted GHG emissions targets in line with the Paris Agreement based on independent and expert advice under the guidance of the Science-Based Targets initiative (SBTi).[1]

The number of companies engaging in environmental action and, more broadly, in Environmental, Social and Governance (ESG) strategies has surged in recent years (Perez et al., 2022). Incorporating those factors into companies' strategies can improve their competitive advantage by (1) reducing both idiosyncratic and systemic risks (Freeman, 1984; Godfrey, 2005; Kurucz et al., 2008; Clark et al., 2015; Dahlmann et al., 2019;), (2) reduce operative costs (Porter and Kramer, 2002; Kurucz et al., 2008), (3) generate brand recognition among stakeholders (Dahlmann et al., 2019) and (4) attract environmentally conscious customers, employees, and investors (Godfrey, 2005; Kurucz et al., 2008; Clark et al., 2015; Dahlmann et al., 2019).

Moreover, participating in social or environmental activities beyond regulatory requirements can be seen as an integral part of the firm's stakeholder approach (Freeman, 1984). According to this theory, by considering the views and demands of key stakeholders such as employees, clients, suppliers, government agencies, and retailers, among others, the firm can create long-term economic value.

In addition to generating economic value, adopting and improving social and environmental practices helps to mitigate physical and financial risks. A key argument for engaging in such

[1] See https://sciencebasedtargets.org.

practices is that firms create moral capital that attenuates punitive actions taken against the firm (Godfrey, 2005). This may be more important for companies in risky sectors due to their higher reliance on fossil fuels such as oil and gas, aviation, and transportation.

In contrast, according to the traditional shareholder view of the firm, integrating the views of stakeholders, including by engaging in social and environmental projects beyond what is mandated by law, entails an inefficient level of risk management, which prioritizes risk-averse decisions leading to poor investment decisions (Sundaram and Inkpen, 2004). Yet, managers may engage in socially responsible activities that are costly and generate negative cash flows in the short term but that maximize the market value of the firm in the long term (Mackey et al., 2007).

To our knowledge, the analysis of the market performance of setting GHG targets is, for the most part, non-existent. Most related literature focuses on the relationship between financial performance and ESG strategies. However, there are no unified guidelines and frameworks for rating ESG performance, making it difficult to assess in practice (Amel-Zadeh and Serafeim, 2018; Florian et al., 2019). In contrast, setting GHG targets focuses on a particular environmental aspect that is comparable across companies and, more importantly, addresses one of the most urgent planetary challenges: climate change.

This paper analyzes the short-run effects of committing and setting GHG targets on companies' stock price returns and volatility. The focus of the paper is on companies that partnered with SBTi to commit and set GHG targets. The partnership with SBTi ensures that GHG targets are independently assessed and validated using scientific knowledge and based on plausible trajectories. Companies committing to a GHG target in partnership with SBTi follow several steps to set GHG targets (see Section 3 for a detailed description of the process). The first step is the company signaling to SBTi its commitment to set a target, followed by setting a particular target that involves analysis and validation by SBTi.

Despite being the most renowned global initiative for guiding and assisting companies in reducing their GHG emissions in alignment with the Paris Agreement, to our knowledge, there are no studies assessing the market effects of committing and setting GHG targets under the SBTi initiative.

To conduct our analysis, we use data available on the SBTi website, which contains firms' name, sector, and location data, along with the stage in SBTi's process: committed companies (*committed*) or companies that have set their targets (*target-set*). The former includes companies that have formally expressed their intention to work with the SBTi to set a GHG target and the date the commitment occurred. The latter category (*target-set*) includes those firms that have set a GHG target. Importantly, for *target-set* companies, the SBTi does not report the date at which they committed to set a target.

We focus on publicly traded companies with available stock price information (1,379 companies in our sample). We employ two empirical approaches to estimate the market effects in the mean and volatility of stock prices before and after a commitment or a target were set. First, we apply a generalized autoregressive conditional heteroskedasticity (GARCH) model with a trend, per company in our sample, to estimate differences between mean stock returns and volatility trends (Guerrero et al., 2016; Uribe et al., 2018). The advantage of this model is that it allows us to simultaneously test the impacts of GHG targets on stock returns and volatility trends. Second, we exploit the panel nature of our data set and estimate a fixed effects model on stock returns and monthly price volatility levels.

We conduct the analysis using three samples. The first sample pools together all firms (*committed* and *target-set*). The second sample splits companies by their status in the SBTi process. Finally, the third sample includes companies for which we obtained information on both the date when they committed and the date when they set a target. To do this, we collected information from SBTi's website in two time periods: May 2021 and May 2022. We identified 117 companies with both commitment and target set dates. Using those companies, we also test the effects of committing and setting targets simultaneously using the fixed effects model.

The results from both the GARCH with trend and the fixed effects model show no statistically significant impact of committing or setting a target on average stock returns. However, both models show that committing to a target reduces monthly stock price volatility. However, in our panel specification, provided a company has committed to a target, setting a target appears to have no statistically significant impact on price volatility. Moreover, when controlling for pre- and post-intervention trends, the effect of committing to a target on price volatility is not statistically significant. We conclude that there are no visible market gains from committing and/or setting a GHG target. Other than pure market reasons may be motivating companies to set GHG targets.

This paper is structured as follows. The second section presents a brief summary of the empirical evidence on the subject. Section 3 describes the Science-Based Targets initiative. Section 4 describes the data collection process and the data used in our analysis. Section 5 describes the methodology. Section 6 presents the results. Section 7 performs robustness checks, and Section 8 concludes.

2 Literature Review

The number of studies analyzing the impacts of environmental practices and management on financial performance is large. While a comprehensive literature review of this topic is beyond the scope of this paper, this section intends to showcase the conclusions of a set of articles on the subject and offer a broad view of the directions of their results.

Most of the literature on the topic concentrates on analyzing the impact of ESG actions or ratings on corporate financial performance or on the financial impacts of reducing GHG emissions. This section summarizes some of the main findings in the empirical literature linking financial performance, ESG, and sustainability practices.

Based on a comprehensive global survey of senior investment professionals, Amel-Zadeh and Serafeim (2018) found that investors focus on ESG factors because they consider them financially material. Yet, according to the authors, almost 30% of the investors responded that integrating ESG factors into investment decisions has no significant effect on the investment properties of portfolios. A meta-analysis conducted in 2015 of more than 2000 studies focusing on the relationship between ESG performance and CFP found a non-negative (either positive or neutral) relationship between ESG performance and CFP (Friede et al., 2015).

Using data on Korean firms, Yoon et al. (2018) discovered a positive correlation between ESG scores and firms' stock prices. However, the effect was weaker for firms belonging to environmentally sensitive sectors. Engelhardt et al. (2021) found that an increase in ESG ratings tends to improve stock market performance and reduce price volatility for European firms, mainly due to improvements in the governance component. Serafeim and Yoon (2022) found that the number of positive ESG news increases stock prices. Moreover, their results indicate that investors react mainly to unexpected news. Lastly, Shanaev and Ghimire (2022) assessed the impact of changes in ESG ratings on stock returns of 748 US firms and found that higher scores are associated with higher stock returns.

Kuo et al. (2010) found that corporate financial performance (CFP) improves with lower GHG emissions and attributes this result to productivity gains and more innovation directed at more efficient and cheaper manufacturing processes. Trinks et al. (2020) added that investors' confidence is higher toward more eco-efficient companies and that, in some cases, institutional investors may pressure companies to adopt measures to reduce their GHG emissions. Also, firms can strengthen brand reputation via more environmentally friendly production, gaining consumers who avoid products from more pollutant firms (Hart and Ahuja, 1996).

Although most studies find a positive relationship between corporate environmental performance (CEP) and CFP, a few studies show that reducing GHG emissions can have adverse economic effects. For example, Folger-Laronde et al. (2020) concluded that higher ESG ratings do not mitigate the impacts of adverse market shocks, while La Torre et al. (2020) observed that higher ESG scores do not significantly affect stock price returns because investors receive information about how firms undertake ESG measures with some lag. Brouwers et al. (2018) states that, in some cases, the cost of mitigating GHG emissions could exceed the benefits, negatively affecting CFP.

While the evidence on the relationship between corporate social performance and financial returns has been extensively studied, the relationship between corporate social performance and financial risk has received limited attention in the literature. Ayton et al. (2022) is one of the few studies that explore this relationship for large UK companies, looking at both idiosyncratic and systematic risk. In contrast with previous findings, this study did not find causality between risk types and corporate social performance as measured by an aggregate ESG score measured at the monthly level.

3 The Science-Based Targets Initiative

The Science-Based Targets initiative is a partnership of international organizations that sets sector-specific GHG emission targets guidelines and frameworks for the private sector in line with the Paris Agreement goals.[2] SBTi also provides technical support to companies that set GHG emissions targets to help them achieve their targets and perform independent assessments and validation of targets.

GHG targets cover direct emissions from sources owned or controlled by the company (scope 1) and indirect emissions from the generation of purchased energy (scope 2). When emissions from the company value chain (scope 3) surpass 40% of scope 1, 2, and 3 emissions, then targets also cover scope 3 emissions.

Companies that set a target undergo a five-step process: (1) letter submission establishing their intent to fix a science-based target (Commitment); (2) target definition according to SBTi's guidelines (Development); (3) presentation of the target to SBTi for official validation (Submit); (4) target announcement to stakeholders and the public (Communicate Target); (5) report company-wide emissions and track progress towards the target (Disclose).

Setting a commitment is a relatively straightforward step requiring companies to submit a letter committing to a target. At that stage, the SBTi recognizes that company as committed, publishes it into its list of committed companies, and communicates its status to SBTi's partners. Once committed, the company has 24 months to submit its targets to the SBTi. During that period, SBTi helps companies develop their emissions targets and the paths to achieve them. Targets can be defined in line with a 1.5 or 2-degree pathway. Once companies have set their targets, they submit them to SBTi for validation. This step can take a few months and be subject to revisions and rejections. If the target is approved, SBTi publishes the company's name on its partners' websites. Companies must communicate to the public their targets within six months of approval. The last step requires companies to track their emissions and disclose them annually.

This process ensures that a company setting a target in partnership with the SBTi is committed

[2] These include CDP, the United Nations Global Compact, World Resources Institute (WRI), and the World Wildlife Fund (WWF).

to keeping its GHG emissions under control and that its emissions will be monitored and evaluated against those commitments.

The SBTi is not the only initiative promoting business alignment with the Paris Agreement goals. Other initiatives include The Climate Pledge, SOS 1.5, and 1.5 C Supply Chain Leaders. We focus on SBTi because it is the initiative that most companies adhere to, covering over a third of global economy market capitalization and focusing on both scopes 1 and 2 emissions. Initiatives like The Climate Pledge are relatively new, with only 200 members. In contrast, SOS 1.5 initiative and 1.5 C Supply Chain Leaders cover other aspects of sustainability and emissions along the supply chain (scope 3 GHG emissions).

4 Data

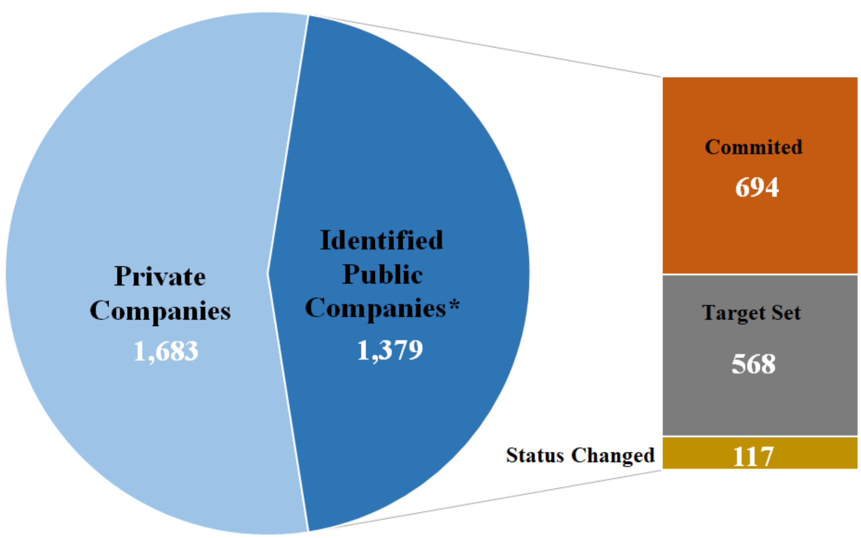
The number of companies incorporating GHG emissions targets has increased rapidly. According to a recent list of companies (accessed on May 2022), more than three thousand companies are working with SBTi, of which 52 percent had committed to setting a target, and 48 percent had a GHG emission reduction target.

Unfortunately, the SBTi database does not provide a historical account of the evolution in the status of the partner companies. Thus, from the publicly available data, it is not possible to identify when companies changed status from *committed* to *target-set*. To address this limitation, we collected SBTi data in two time periods: May 2021 and May 2022. By combining these two lists, we identified companies that appeared with a commitment status in May 2021 and that, by May 2022, had set targets.

Regarding information on stock prices, out of the more than 3,000 companies working with the SBTi, we could only find stock price data for 1,379 (which we denominate as public). This matching involved several stages (see Appendix A for a detailed explanation of the data collection process). First, we selected the companies with a ticker in Bloomberg. Second, we identified those tickers that experienced changes since 2015. Among these changes, we found (1) suspension of the tickers, (2) limited stock trading frequency, (3) mergers and acquisitions, and (4) companies whose tickers changed for other reasons. Companies within the first three cases were removed from the data, while, for companies in the fourth case, we updated their price series with the new ticker.

We also excluded companies with missing price data within 30 days before and after committing or setting a target. This situation occurred for eight committed companies and 15 with a defined target. It is essential to highlight that in this step, we treated companies for which we have information on the date they committed and later on the date they set a target as a particular case because we had to ensure they had price data for both events (one company did not satisfy the criteria and was excluded). Figure 1 shows the results of all the data-cleaning processes described above. There we see that our final a data-set comprises 1,379 firms, with stock price data from January 2015 to May 2022. Out of those, 694 are *committed*, 568 are *target-set*, and for 117, we have information on both the dates they became *committed* and on the date they became *target-set*.

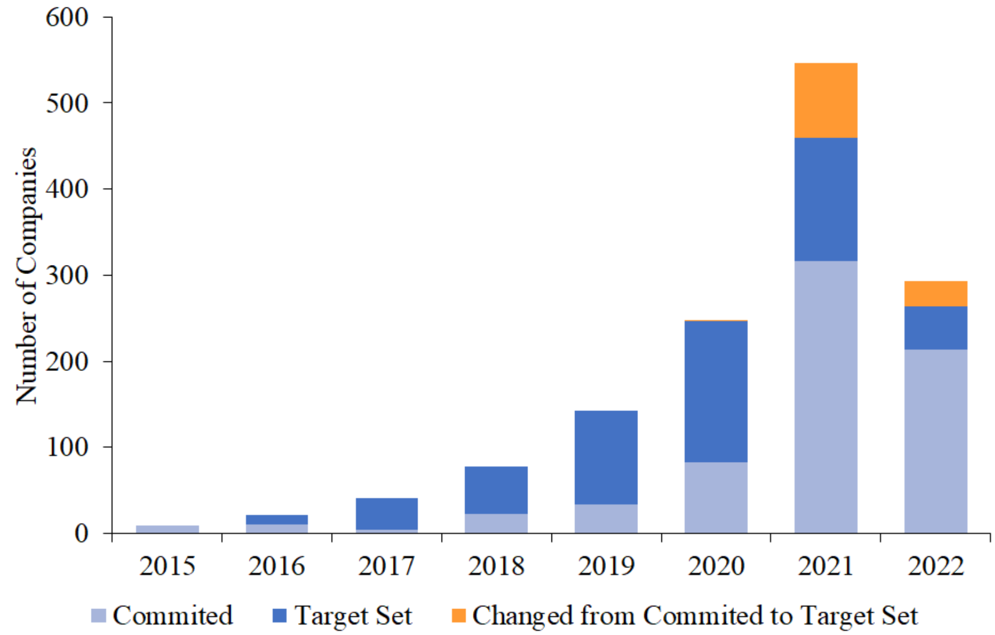
Figure 1: Proportion of Public and Private Companies with GHG Emissions Commitments and Targets in SBTi



Source: Authors elaboration based on SBTi (2022)

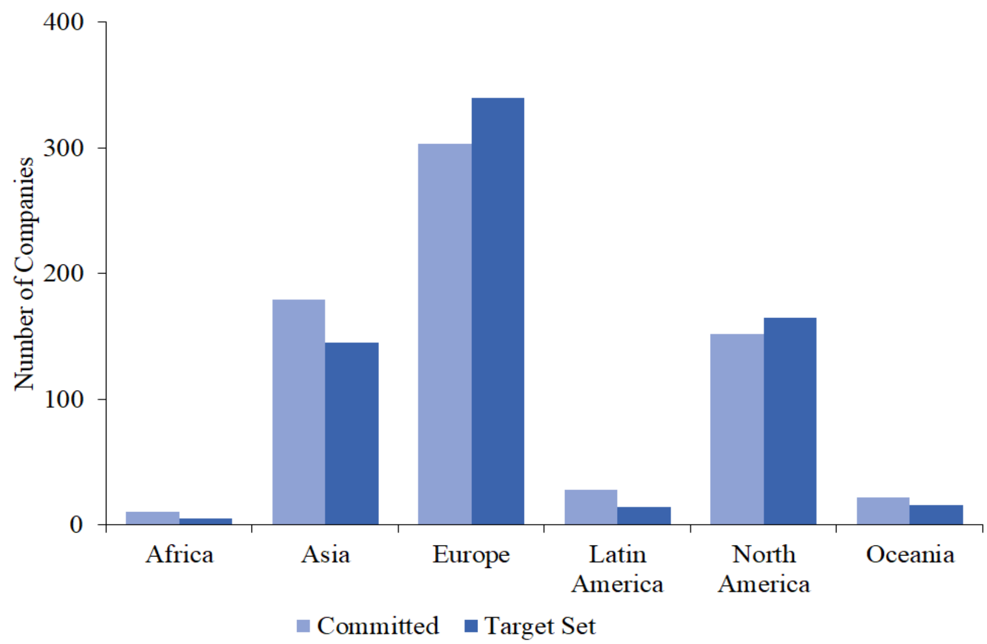
The number of companies committing to implement GHG targets has grown rapidly since 2015 (see Figure 2). Most of the public companies in the data are located in Europe, Asia, and North America, whereas Latin America, Oceania, and Africa have the least number of public companies either with a commitment or with a target set (see Figure 3).

Figure 2: Number of Public Companies with GHG Commitments and Targets per Year



Source: Authors elaboration based on SBTi (2022)

Figure 3: Number of Public Companies with GHG Commitments and Targets by Region



Source: Authors elaboration based on SBTi (2022)

Companies in our sample belong to multiple sectors. The top five industries with the most significant number of *committed* companies are Computing, Financial Services, Transportation, Electrical Equipment and Machinery, and Construction and Building. The sectors with more *target-set* firms are Food, Beverages and Tobacco, Real Estate, Computing, Construction and Building, and Electrical Equipment and Machinery (see Table 1).

Table 1: Number of Public Companies with GHG Commitments and Targets by Sector

Sector	Committed	Target Set	Total by Sector
Chemicals	28	13	41
Computing	85	64	149
Construction and Building	51	56	107
Consumer Durables, Household and Personal Products	16	35	51
Containers and Packaging	5	10	15
Education Services	-	2	2
Electrical Equipment and Machinery	54	51	105
Financial Services	80	13	93
Food, beverages and tobacco	37	88	125
Forest and Paper Products - Forestry, Timber, Pulp and Paper, Rubber	12	12	24
Healthcare and pharmaceuticals	32	32	64
Hotels, Restaurants and Leisure, and Tourism Services	18	15	33
Media	11	10	21
Oil, Gas and Mining	17	11	28
Professional Services	26	28	54
Real Estate	34	69	103
Retail	28	26	54
Specialized Consumer Services	7	2	9
Telecommunications	15	35	50
Textiles	31	27	58
Trading Companies and Distributors, and Commercial Services and Supplies	16	6	22
Transportation	59	46	105
Utilities	32	34	66
Total	694	685	1379

Source: Authors elaboration based on SBTi (2022)

Lastly, Table 2 presents the summary statistics of the price data of the companies in our sample. They exhibit a large dispersion in stock prices, with an average of 1,692 USD per stock and a standard deviation of 13,495. Daily stock returns are 0.01% on average, with a standard deviation of 0.023. At a monthly frequency, the standard deviation of the daily returns is 0.01, with a minimum of 0 and a maximum value of 0.57.[3]

[3] We test for a unit root on daily returns for each of the firms in our sample using the Augmented Dickey-Fuller test. The results reject the null hypothesis; see Appendix B.

Table 2: Summary Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Price (USD)	2,502,974	1,692.40	13,495.15	0.004	361,000
Daily returns	2,501,596	0.00016	0.023	-1.74	2.36
Std. Dev. of daily returns	115,353	0.01800	0.013	0	0.57

Source: Authors elaboration based on SBTi (2022)

5 Methodology

We employ two approaches to test the stock market effects of committing and setting GHG targets. First, we implement a novel methodology that allows us to simultaneously test for changes in the drift and the variance of returns based on the GARCH with trend model developed by Guerrero et al. (2016) and Uribe et al. (2018). The advantage of this approach is that it allows us to test for changes in price returns and volatility trends by imposing a structural form on the error term of the return process that explicitly incorporates a drift within the conditional variance of a classical GARCH(1,1).[4]

Our second approach exploits the panel structure of our data and implements a fixed effects model on returns and monthly volatility separately. While this approach does not impose any particular structure on the error terms, it allows us to control for time-invariant firm-level characteristics that could influence the timing of commitment and target set and allows us to control for sector-level trends and other macroeconomic shocks.

5.1 GARCH with Trend

Our aim with this approach is to test if returns and stock price volatility are stable within a time interval. In particular, if they are stable after committing or setting a target. The stock returns are modeled as a geometric Brownian motion:

[4]We select a GARCH(1,1) following Namugaya et al. (2014). Also, statistical significance tests for all parameters in the more than 1,300 GARCH models are performed. We report the p-values for each parameter in histograms in Appendix C.

$$S_t = S_0 \exp\left\{\sum_{j=1}^{t} \varepsilon_j\right\}, \tag{1}$$

where S_t is the stock price at time t and S_0 is its present value. In particular, a process ε within a time interval $t \in [1,\ldots,n]$ is assumed to follow the dynamics:

$$\varepsilon_t = \mu + \sigma_t w_t, \qquad w_t \overset{i.i.d}{\sim} \mathcal{N}(0,1), \tag{2}$$

where μ is the mean of ε_t and σ_t is the standard deviation of the returns or the volatility of the asset prices S.[5]

Hence, for each firm, we test whether the changes in the mean and volatility of stock prices before and after a commitment or a target were set are significant. For the period before a firm commits or sets a target, we estimate the model:

$$\sigma_t^2(\beta_1,\mu_1) = \alpha_0 + \alpha_1(\varepsilon_{t-1} - \mu_1)^2 + \beta_1 t + \gamma\sigma_{t-1}^2(\beta_1,\mu_1). \tag{3}$$

For the period after a firm commits or sets a target, we estimate the following model:

$$\sigma_t^2(\beta_2,\mu_2) = \alpha_0 + \alpha_1(\varepsilon_{t-1} - \mu_2)^2 + \beta_2 t + \gamma\sigma_{t-1}^2(\beta_2,\mu_2). \tag{4}$$

5.2 Fixed Effects Model

While the GARCH with trend model allows us to test simultaneously for changes in the mean and the trend in the volatility of stock prices, it cannot control for firms' characteristics that may influence the likelihood of committing or setting a target. To control for those factors, we estimate the following fixed effects model:

[5] The statistical properties of the model can be found in Guerrero et al. (2016).

$$r_{i,t} = \alpha_i + \lambda_m y + \sum_{j=1}^{8} \beta_j W_j + \sum_{k=1}^{4} \gamma_k MS_k + \sum_{s} Sec_s * Trend + e_{it}, \tag{5}$$

where r denotes stock returns ($\log(price_{i,t})$-$\log(price_{i,t-1})$) and subscripts i and t represent company and transaction week, respectively. The parameter α_i stands for firm fixed effects, $\lambda_m y$ are vectors of month by year dummies. To capture the dynamic effects of committing or setting targets, we create eight dummies W_j with $j = 1 \ldots 8$ representing the number of weeks after a company committed or set a target, including the week when it committed or set a target, and e_{it} stands for the error term. We also estimate those effects separately by splitting the sample into those companies that appear with a commitment status in the SBTi database and those that appear under a target set status. Given the time period covered in our sample, we control for some important financial and macroeconomic events that occurred during the period of analysis. Particularly the crash of the Chinese stock market in 2015, the drastic fall in oil prices in early 2016, the Volpokalipse episode in 2018 (an unexpected event of high volatility in the stock market in 2018), and the COVID-19 pandemic in 2020. These are represented by the dummies MS_k with $k = 1, \ldots, 4$. [6] Finally, we also control for sector-level trends by introducing sector-by-trend dummies: $Sec_s * Trend$.

To test the effect of either committing or setting GHG targets on price volatility, we also exploit the panel structure of our data and estimate a fixed effects model of the monthly standard deviation of stock returns as follows:

$$vol_{i,t} = \alpha_i + \lambda_t + \beta GHGTarget + \sum_{k=1}^{4} \gamma_k MS_k + \sum_{s} Sec_s * Trend + u_{it}, \tag{6}$$

where vol represents the monthly standard deviation of returns as represented by the dependent variable in equation 5. Subscripts i and t denote firm and time (month of the year), respectively. α_i stands for firm fixed effects, λ_t are month-by-year dummies, and u_{it} is the error term. In contrast to the weekly dummies we use in the specification of daily returns, in this specification, we only include a dummy variable ($GHGTarget$) that takes a value of one for the period after a company

[6] We dated the Chinese stock market crash from June 12 to August 31, 2015; Oil prices fall from January 6 to February 21 2016; the Volpokaplipse episode from February 5 up to March 1, 2018; and the pick of the COVID-19 pandemic from February 20 up to March 24, 2020.

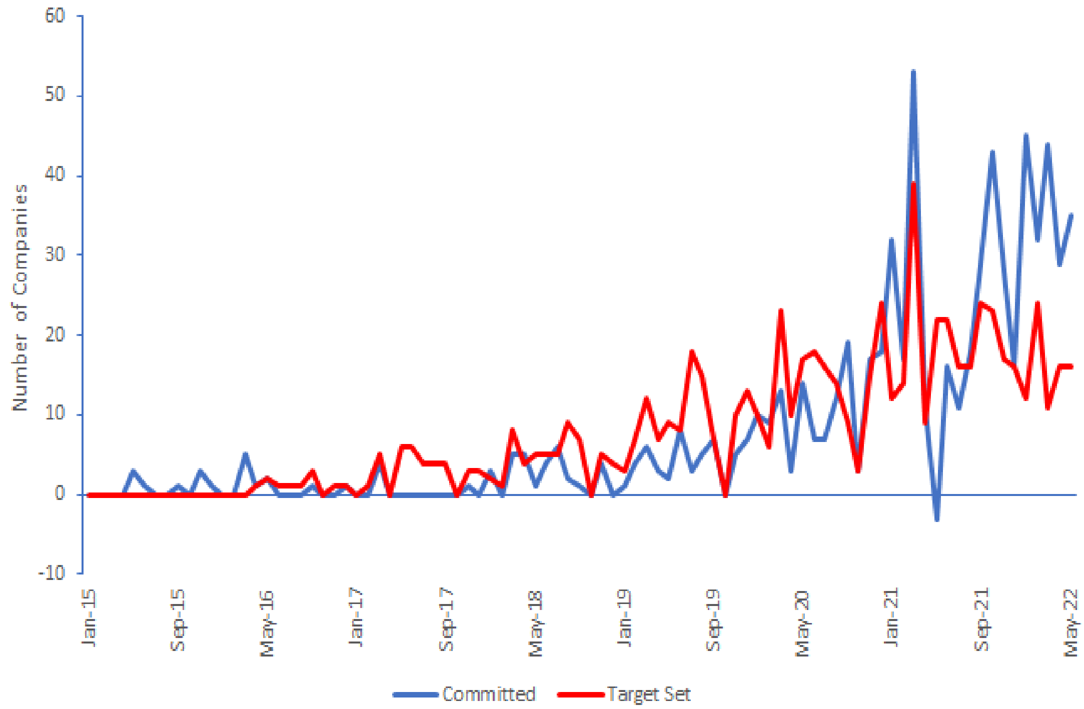
committed or set a target and zero otherwise. Macroeconomic shocks that affected stock markets are represented by the dummies *MS*, and sector-by-trend dummies are included in the vectors $Sec_s * Trend$.

As the introduction explains, multiple factors can induce a company to commit or set a target. Since we only focus on *committed* and *target-set* companies, the identification assumptions of this empirical strategy rely on the timing at which companies either commit or set targets. As stated by SBTi (2022), both actions seem to have increased over time, likely driven by a growing awareness of the climate crisis in the private sector, anticipation of more stringent regulations, heightened climate diplomacy efforts via the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), as well as the capacity of SBTi to process and guide companies when committing and setting a target.

Figure 4 shows the monthly change in companies setting or committing to a target. There has been a rapid growth in the number of firms working with the SBTi. In particular, in March and October of 2021. It is not clear what particular event may have triggered the increased activity on the first date. The second date was likely linked to the COP26 event in Glasgow, reaffirming our hypothesis that climate awareness and significant global initiatives may be major drivers for companies setting and committing to GHG targets.

To the extent that growing awareness varies by sector and characteristics inherent to firms, controlling for trends by sector dummies and firm fixed effects should be sufficient to identify the parameters in (5) and (6). Month-by-year dummies capture global events. Companies could, however, manipulate and decide when target announcements take place. For example, they could decide to announce setting the targets right after a bad day or week in the stock market. Part of those biases could be alleviated by including time dummies, but we acknowledge that those may not be sufficient to reduce all biases stemming from firms' market motivations.

Figure 4: Monthly Change in the Number of Companies Setting and Committing to Targets



Source: Authors elaboration based on SBTi (2022)

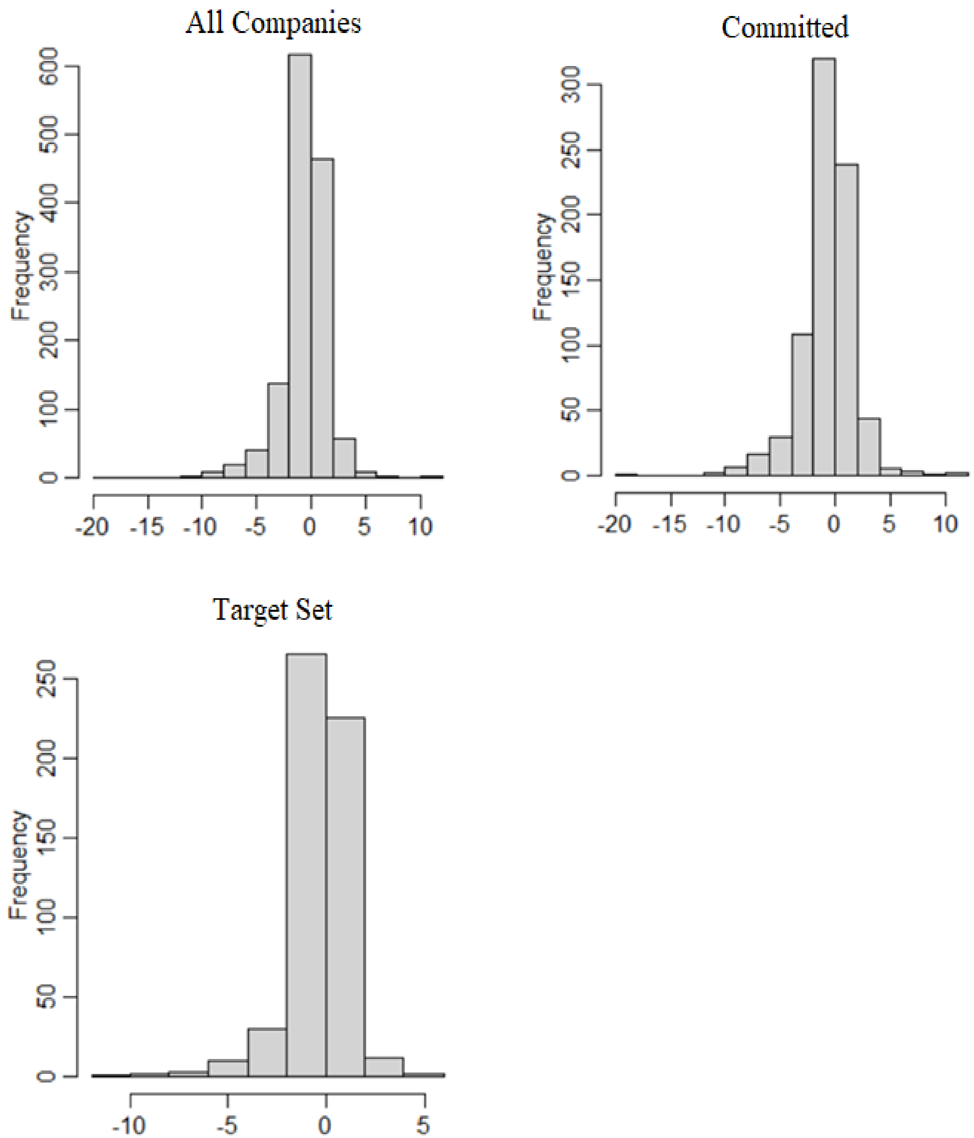
6 Results

This section presents the estimated effects of committing or setting a GHG emissions target on average returns and stock price volatility as estimated by our proposed methods. We report the results separately for returns and volatility using three main samples. The first sample consists of all firms (*committed* and *target-set*). The second sample splits companies by their status in the SBTi process (*committed* or *target-set*). Finally, the third sample includes companies for which we collected information on both the date when they committed and the date when they set a target.

6.1 Stock Returns

Results from our GARCH with trend model show no difference in mean stock returns parameters before and after companies became *committed* or *target-set*, (see Figure 5). On average, the differences between the *after* and *before* estimated parameters are centered around zero for the majority of the sample of *committed* companies and the sample of *target-set* companies. Table 3 third column presents the p-values from a t-test of the difference in means of average returns before and after the change in status. These confirm that there are no statistically significant differences between average returns at the 5 percent level.

Figure 5: Difference in Mean Stock Returns Parameters (μ_1 and μ_2)
After Commitment/Target vs Before Commitment/Target



Source: Authors elaboration based on SBTi (2022)

Using the full sample, the results from the fixed effects model suggest that neither committing nor setting a target has a statistically significant effect on stock returns in the following weeks after the status was made public, see Table 4. In particular, most of the week dummies are not statistically significant. Distinguishing between *committed* from *target-set* firms does not change the results as most week dummies are not statistically significant (Tables 5 and 6). The macroeconomic shocks of COVID and VOL2018 show statistically significant effects with opposite signs. As expected, the COVID effect is negative.

Table 3: P-values of Mean Differences in Volatility and Mean of Stock Price Returns

	Volatility F-test	Mean t-test
All	< 0.000	0.095
Target Set	< 0.000	0.102
Committed	< 0.000	0.090

Source: Authors elaboration based on SBTi (2022)

For those companies for which we can identify the date when they changed status from *committed* to *target-set*, we adapt the model specification from equation 5 to make it more parsimonious by including four-time dummy variables for the weeks after a company became *committed*, and four dummies for the weeks after a company became *target-set* (the results remain if we include eight-week dummies per status). Results of this specification are shown in Table 7. The results are consistent with the findings, including all companies: we find no evidence of a statistically positive or negative effect on stock returns of either action. All macroeconomic shocks, except for the VOL2018, adversely affected average returns, with COVID being the most adverse factor affecting stock returns, as expected.

6.2 Volatility

The GARCH with trend estimates shows that, on average, there is a significant reduction in volatility trends after companies commit or set a target (see Figure 6). For the majority of firms in our sample (regardless of how we partition it: all companies, *committed*, or *target-set*), the differences between the *after* and *before* estimated parameters of trend volatility are negative. As in the previous case, we also assess the statistical significance of these results by performing an F-test of the differences in volatility trends for all the GARCH models estimated. We report the average value of the p-values obtained from such test in Table 3 second column. In contrast with the case for stock returns, we now find that the difference is statistically significant for all companies, *committed* and *target-set* at a 99.5% level.

Table 4: Impact of Committing or Setting a GHG Target on Stock Returns

	(1)	(2)
Week 0	-0.000458	-0.000526^{*}
	(0.173)	(0.100)
Week 1	-0.0000307	-0.0000514
	(0.889)	(0.804)
Week 2	-0.0000758	-0.0000861
	(0.848)	(0.830)
Week 3	-0.000654^{*}	-0.000505
	(0.094)	(0.172)
Week 4	-0.000319	-0.000335
	(0.372)	(0.328)
Week 5	0.000141	0.0000633
	(0.704)	(0.859)
Week 6	-0.000526	-0.000566
	(0.180)	(0.167)
Week 7	0.000151	0.000104
	(0.698)	(0.778)
CRASH2015		-0.000283
		(0.300)
OILfall		-0.000589^{*}
		(0.090)
VOL2018		0.00652^{***}
		(0.000)
COVID		-0.0306^{***}
		(0.000)
R-squared	0.00789	0.0163
Observations	2,501,596	2,501,596
Groups	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (4). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

Table 5: Impact of Committing to a GHG Target on Stock Returns

	(1)	(2)
Week 0	−0.000534	−0.000644
	(0.233)	(0.133)
Week 1	0.000477	0.000414
	(0.324)	(0.381)
Week 2	0.000834*	0.000781*
	(0.067)	(0.087)
Week 3	−0.000974*	−0.000870*
	(0.070)	(0.092)
Week 4	−0.0000325	0.0000497
	(0.949)	(0.916)
Week 5	0.000115	0.000145
	(0.820)	(0.777)
Week 6	0.000502	0.000483
	(0.316)	(0.375)
Week 7	−0.0000673	−0.0000934
	(0.895)	(0.846)
CRASH2015		−0.000397
		(0.397)
OILfall		−0.000516
		(0.137)
VOL2018		0.00666***
		(0.000)
COVID		−0.0313***
		(0.000)
R-squared	0.00776	0.0157
Observations	1,443,870	1,443,870
Groups	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (4). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

Table 6: Impact of Setting GHG Targets on Stock Returns

	(1)	(2)
Week 0	−0.000342	−0.000358
	(0.406)	(0.399)
Week 1	−0.000710	−0.000677
	(0.168)	(0.187)
Week 2	-0.00123^{**}	-0.00118^{**}
	(0.027)	(0.030)
Week 3	−0.000222	−0.0000188
	(0.513)	(0.955)
Week 4	−0.000694	−0.000834
	(0.172)	(0.102)
Week 5	0.000173	−0.0000349
	(0.760)	(0.953)
Week 6	-0.00176^{***}	-0.00183^{***}
	(0.005)	(0.004)
Week 7	0.000497	0.000424
	(0.482)	(0.546)
CRASH2015		−0.000128
		(0.637)
OILfall		−0.000686
		(0.179)
VOL2018		0.00632^{***}
		(0.000)
COVID		-0.0296^{***}
		(0.000)
R-squared	0.00848	0.0178
Observations	1,057,726	1,057,726
Groups	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (4). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

Table 7: Impact of Committing and Setting a GHG Target on Stock Returns for Firms with Identified Date of Status Change

	(1)	(2)
Week 0 committed	0.000434	0.000116
	(0.712)	(0.925)
Week 1 committed	0.00186	0.00163
	(0.146)	(0.183)
Week 2 committed	−0.000594	−0.000800
	(0.419)	(0.283)
Week 3 committed	0.000153	0.000292
	(0.923)	(0.852)
Week 0 target	−0.000495	−0.000516
	(0.457)	(0.441)
Week 1 target	0.00158*	0.00157*
	(0.057)	(0.058)
Week 2 target	0.00110	0.00111
	(0.232)	(0.232)
Week 3 target	−0.00221*	−0.00221*
	(0.060)	(0.061)
CRASH2015		−0.000286
		(0.505)
OILfall		−0.000487
		(0.533)
VOL2018		0.00577***
		(0.000)
COVID		−0.0259***
		(0.000)
R-squared	0.00820	0.0152
Observations	219,366	219,366
Groups	20	20

p-values in parentheses

Month by year and sector by trend fixed effects included but not reported. Clustered standard errors at sector level.

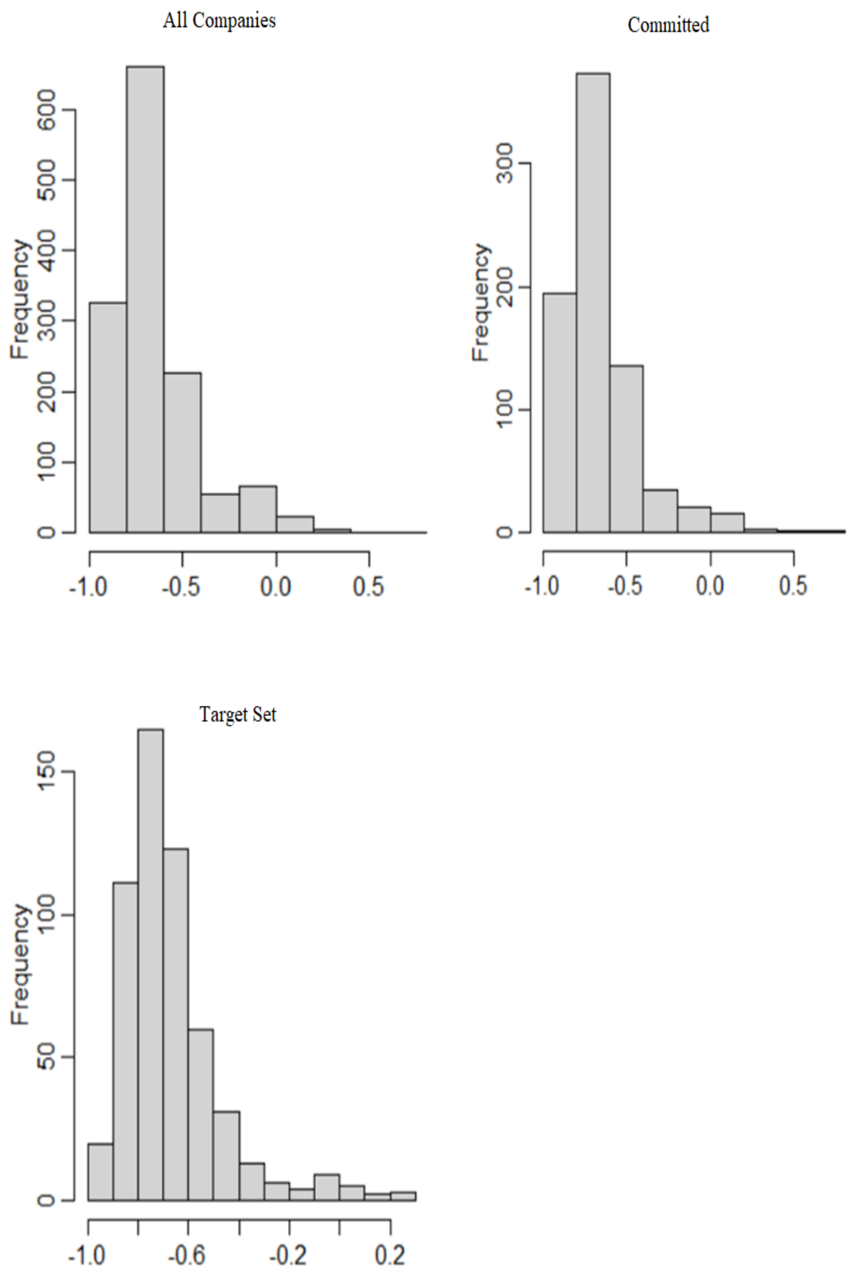
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (4). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

The fixed effects model results show a significant and negative effect on stocks' volatility of committing or setting a GHG emission target (Table 8). However, when we differentiate between the companies that committed from those that set targets, we find no statistically significant effect on stock volatility for the latter group (see Tables 9 and 10). This contrasts with our GARCH results, where both setting targets and committing to a target resulted in adverse and statistically significant effects on stock returns volatility. The relative magnitude of the estimates indicates that the effect of committing to a target produced a 6% decline in the volatility of stock returns for committed firms and a 4% decline relative to all firms in the sample (provided average standard deviations of daily returns were 0.011 and 0.018 for *committed* firms and the whole sample, respectively).

Figure 6: Difference in Trend Volatility Parameters (After Commitment/Target -Before Commitment/Target)



Source: Authors elaboration based on SBTi (2022)

Table 8: Impact of Committing or Setting a GHG Target on Volatility

	(1)	(2)
GHG Target	-0.000707^{***}	-0.000707^{***}
	(0.004)	(0.004)
CRASH2015		-0.00343^{***}
		(0.000)
OILfall		0.00570^{***}
		(0.000)
VOL2018		-0.00168^{***}
		(0.005)
COVID		0.0394^{***}
		(0.000)
R-squared	0.308	0.308
Observations	115,353	115,353
Groups	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at the sector level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (5). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

The macroeconomic shocks had differentiated effects on stock volatility. While the plummet of oil prices in early 2016 and the COVID-19 pandemic period resulted in higher stock volatility, the Asian stock market crash and the Volpokalipse episode unexpectedly had a negative and significant effect coefficient, suggesting that stock volatility of companies working with the SBTi decreased during these events. When differentiating by status, we find positive effects of all macroeconomic shocks on the volatility of stock returns. The COVID effect is positive and has the largest magnitude in all specifications.

Panel estimates for companies with identified changes in both status, *committed* and *target-set*, show a negative effect on stock price volatility after companies commit to a target, albeit the effect is statistically significant at the 10% level (see Table 11). We find no statistically significant effect on companies that changed from committed to target-set. In this case, all macroeconomic shocks except for VOL2018 increased stock volatility.

Table 9: Impact of Committing to a GHG Target on Volatility

	(1)	(2)
GHG Target	-0.00107^{**}	-0.00117^{***}
	(0.011)	(0.007)
CRASH2015		0.00227^{***}
		(0.000)
OILfall		0.0101^{***}
		(0.000)
VOL2018		0.00570^{***}
		(0.000)
COVID		0.0193^{***}
		(0.000)
R-squared	0.131	0.185
Observations	66,584	66,584
Groups	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at the sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (5). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

Table 10: Impact of Setting a GHG Target on Volatility

	(1)	(2)
GHG Target	-0.000607^{*}	-0.000446
	(0.064)	(0.132)
CRASH2015		0.00104^{***}
		(0.000)
OILfall		0.00955^{***}
		(0.000)
VOL2018		0.00589^{***}
		(0.000)
COVID		0.0182^{***}
		(0.000)
R-squared	0.156	0.219
Observations	48,769	48,769
Groups	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at the sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (5). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

Table 11: Impact of Committing and Setting a GHG Target on Stock Returns Volatility for Firms with Identified Date of Status Change

	(1)	(2)
Committed	-0.00171^{*}	-0.00171^{*}
	(0.059)	(0.059)
Target Set	0.00119	0.00119
	(0.316)	(0.316)
CRASH2015		0.00476^{***}
		(0.000)
OILfall		0.00401^{***}
		(0.000)
VOL2018		-0.000408
		(0.597)
COVID		0.0366^{***}
		(0.000)
R-squared	0.338	0.338
Observations	10,114	10,114
Groups	20	20

p-values in parentheses

Month by year and sector by trend fixed effects included but not reported. Clustered standard errors at sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (5). Column (1) excludes financial and macroeconomic shocks. Column (2) includes them.

Authors elaboration based on SBTi (2022)

7 Robustness Checks

In this Section, we check the robustness of our findings via two alternative specifications. The first tests the impacts of committing or setting targets on monthly stock returns to see if the results hold in the medium term (Table 12). The second alternative specification includes time dummies before *commitment* or *target-set* in both the weekly stock returns and the volatility specifications shown in the previous section to check for pre-intervention trends (Tables 13 and 14).

Table 12 shows inconclusive evidence of pre-intervention trends, particularly for *commitment* companies. At the monthly level, the impacts of *commitment* companies appear to be negative and statistically significant only at the month they committed and the following month. For the rest of the samples (all and *target-set* firms), there is no evidence of a statistically significant effect of GHG targets.

Table 12: Impact of Committing to a GHG Target on Monthly Stock Returns

	All	Committed	Target Set
Pre_Month_4	-0.000437^{**}	-0.000291^{*}	-0.000379^{***}
	(0.032)	(0.096)	(0.005)
Pre_Month_3	0.000169	0.000243	0.000198
	(0.390)	(0.275)	(0.195)
Pre_Month_2	0.000305	0.000467	0.000366^{*}
	(0.178)	(0.123)	(0.066)
Pre_Month_1	−0.000176	−0.0000601	−0.000137
	(0.245)	(0.785)	(0.137)
Month_0	−0.0000597	-0.000509^{**}	−0.000255
	(0.800)	(0.046)	(0.201)
Post_Month_1	0.0000924	-0.000609^{**}	−0.000225
	(0.728)	(0.023)	(0.195)
Post_Month_2	−0.000340	0.000148	−0.000153
	(0.202)	(0.556)	(0.294)
Post_Month_3	-0.000371^{*}	−0.000273	-0.000343^{*}
	(0.051)	(0.404)	(0.074)
Post_Month_4	−0.000124	−0.000123	−0.000132
	(0.622)	(0.581)	(0.491)
CRASH2015	−0.000402	−0.000135	−0.000288
	(0.392)	(0.620)	(0.293)
OILfall	−0.000516	−0.000686	-0.000588^{*}
	(0.137)	(0.179)	(0.090)
VOL2018	0.00666^{***}	0.00632^{***}	0.00652^{***}
	(0.000)	(0.000)	(0.000)
COVID	-0.0313^{***}	-0.0296^{***}	-0.0306^{***}
	(0.000)	(0.000)	(0.000)
R-squared	0.0157	0.0178	0.0163
Observations	1,443,870	1,057,726	2,501,596
Groups	23	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (4) with time dummies before and after the change in firms' status for monthly stock returns.

Authors elaboration based on SBTi (2022) .

Focusing on pre-intervention and post-intervention trends in weekly returns, we also find inconclusive evidence of pre-intervention trends, particularly for *commitment* companies (Table 13). Consistent with the findings of the previous section, there is no evidence of statistically significant impacts of GHG targets on weekly stock returns.

Table 13: Impact of Committing to a GHG Target on Weekly Stock Returns

	All	Committed	Target Set
Pre_Week_5	0.00101**	0.000721	0.000877**
	(0.049)	(0.233)	(0.034)
Pre_Week_4	−0.0000810	−0.000190	−0.000142
	(0.879)	(0.676)	(0.724)
Pre_Week_3	−0.000749*	−0.00104	−0.000878**
	(0.057)	(0.212)	(0.041)
Pre_Week_2	0.000251	0.000428	0.000315
	(0.599)	(0.447)	(0.335)
Pre_Week_1	−0.0000117	0.000551	0.000214
	(0.965)	(0.385)	(0.378)
Week_0	−0.000644	−0.000347	−0.000520
	(0.132)	(0.413)	(0.104)
Post_Week_1	0.000414	−0.000666	−0.0000459
	(0.384)	(0.193)	(0.825)
Post_Week_2	0.000781*	−0.00117**	−0.0000814
	(0.087)	(0.030)	(0.838)
Post_Week_3	−0.000871*	−0.0000113	−0.000502
	(0.092)	(0.973)	(0.175)
Post_Week_4	0.0000478	−0.000828	−0.000332
	(0.919)	(0.103)	(0.332)
Post_Week_5	0.0000513	0.000359	0.000185
	(0.927)	(0.608)	(0.616)
CRASH015	−0.000399	−0.000133	−0.000286
	(0.395)	(0.625)	(0.295)
OILfall	−0.000516	−0.000686	−0.000588*
	(0.137)	(0.179)	(0.090)
VOL2018	0.00666***	0.00632***	0.00651***
	(0.000)	(0.000)	(0.000)
COVID	−0.0313***	−0.0296***	−0.0306***
	(0.000)	(0.000)	(0.000)
R-squared	0.0157	0.0178	0.0163
Observations	1,443,870	1,057,726	2,501,596
Groups	23	23	23

p-values in parentheses

Month by year and sector by trend dummies included in all specifications. Clustered standard errors at sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (4) with time dummies before and after the change in firms' status for weekly stock returns.

Authors elaboration based on SBTi (2022) .

Table 14: Impact of Committing to a GHG Target on Volatility

	All	Committed	Target Set
Pre_Month_5	-0.000350	-0.000177	-0.000288
	(0.322)	(0.644)	(0.207)
Pre_Month_4	-0.000713^{*}	-0.000169	-0.000565^{**}
	(0.052)	(0.627)	(0.023)
Pre_Month_3	-0.000616	-0.000436	-0.000580
	(0.261)	(0.332)	(0.115)
Pre_Month_2	-0.000660	-0.000283	-0.000523^{*}
	(0.147)	(0.527)	(0.097)
Pre_Month_1	-0.000597	-0.0000593	-0.000386
	(0.181)	(0.889)	(0.203)
Month_0	-0.000852^{**}	-0.000141	-0.000523^{**}
	(0.037)	(0.726)	(0.028)
Post_Month_1	-0.000827	-0.0000668	-0.000458
	(0.117)	(0.879)	(0.178)
Post_Month_2	-0.00160^{***}	0.000652^{*}	-0.000601^{**}
	(0.001)	(0.070)	(0.048)
Post_Month_3	-0.000271	0.000357	0.0000848
	(0.599)	(0.447)	(0.811)
Post_Month_4	-0.00108	-0.000209	-0.000597
	(0.112)	(0.552)	(0.121)
Post_Month_5	-0.000857	0.00000121	-0.000408
	(0.108)	(0.998)	(0.221)
R-squared	0.398	0.450	0.398
Observations	66,584	48,769	115,353
Groups	23	23	23

p-values in parentheses

Month-by-year-by-country and sector-by-trend dummies included in all specifications. Clustered standard errors at sector level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results from equation (5) with time dummies before and after the change in firms' status for monthly stock returns volatility.

Authors elaboration based on SBTi (2022)

Controlling for pre-intervention trends in the volatility specification shows no robust evidence of pre-intervention trends, particularly in the all and *commitment* samples. The results for the pooled sample remain consistent with the findings in the previous section but show a short-lived effect only for the month when the companies committed or set targets. In contrast to the findings in the previous section, committing to setting a target has no statistically significant effect on price volatility, whereas the effect appears to be negative and statistically significant for *target-set* firms.

8 Conclusions

Many companies are committing and setting ambitious targets to reduce their greenhouse gas emissions (GHG) in line with the Paris Agreement to limit global warming below 2 degrees Celsius. Since adopting the Paris Agreement, more than three thousand businesses and corporations have adopted GHG emissions targets in line with Paris Accord goals and under the guidance of the Science-Based Targets initiative (SBTi). Companies' commitments to reduce GHG emissions and, more generally, improved sustainability practices can potentially generate important market and environmental benefits.

This paper analyzes the short-run effects of GHG targets on companies' stock price returns and volatility. The focus is on those companies that have set GHG targets in partnership with SBTi, provided those targets are independently assessed and validated using scientific knowledge and based on plausible trajectories. In doing so, we intend to gather evidence on the market effects of committing and setting GHG targets.

We employ two empirical approaches to estimate the effects on the mean and volatility of stock prices before and after a commitment or a target were set. First, for each company in our sample, we apply a GARCH model with a trend to estimate differences between mean stock returns and volatility trends. Then, we exploit the panel nature of our data set and estimate a fixed effects model on stock returns and monthly volatility. We also split our sample into two cases: First, we analyze companies for which we only observe whether they are committed or have a specific GHG target; i.e., we only have information on their current status with the SBTi. Second, we study companies with information about the date they committed and when they adopted a GHG emission target (unfortunately, the number of companies in this category represents less than ten percent of our sample).

The results from both the GARCH with trend and the fixed effects models show no statistically significant impacts of committing or setting a target on average weekly stock returns. Moreover, for monthly returns, we find a negative and statistically significant impact for firms that commit to set a target during the month they commit and the following month. This impact disappears in the third month after committing to set a GHG target.

Regarding stock volatility, the GARCH with trend model suggests that there is a significant reduction in price volatility after committing and setting a target. However, in the panel specification, the effect seems to be short-lived and only significant in the month when the status changed.

These results reflect that committing and setting GHG targets do not appear to generate clear short-term market gains in terms of higher returns or lower price volatility. Motivations other than short-term market gains may be driving companies to set GHG targets.

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A Appendix. SBTi Database Collection Process

Since 2015, more than three thousand companies and financial institutions have joined the Science-Based Targets (SBTi) initiative to reduce emissions. The registry of all companies that have joined the initiative is available to the public on SBTi's website. Among the included information, perhaps the most important is the status of the companies' short-term targets. Companies are divided into two categories: target set and committed. A company that has set a target has defined clear pathways to reduce its greenhouse gas emissions, which SBTi has validated.

On the other hand, a company in the committed category has demonstrated its intention to develop a target and submit it for validation in less than 24 months. As mentioned in Section 3, we accessed the SBTi's dataset twice, first in May 2021 and again in May 2022. It allowed us to build a historical account of the evolution of member companies' status when they transition from being committed to having a defined emissions reduction target. This record is an essential contribution of our research, especially given that SBTi does not track such changes. In order to harvest the information for our research purpose, we made certain modifications.

First, since our work focuses primarily on the market effects of SBTi target setting or commitments, our interest was limited to publicly traded companies and information available from January 1st, 2015, to May 30th, 2022. When accessed in May 2021, we identified 796 publicly traded companies with a Bloomberg ticker and available price information. Subsequently, in May 2022, the SBTi's base contained 3,062 companies. Of these, 1,459 firms satisfied the criteria to be part of our dataset; 796 were the same firms identified a year earlier, and 663 were new firms. For the 796 companies, namely the old database, we updated the price series and status if changed from committed to having a target. For the other 633 companies, we retrieved the entire price series.

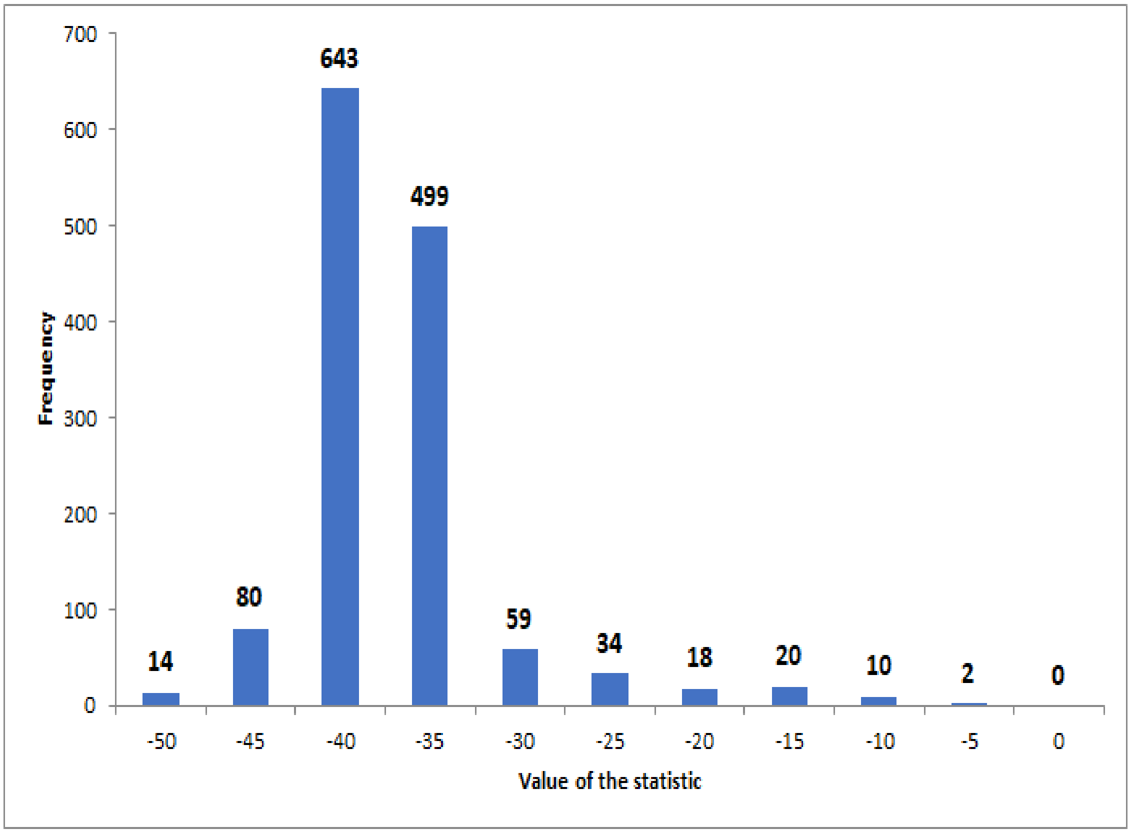
Upon closer examination, we removed 56 companies from the 1,459 in our sample because they either had suspended tickers or a minor trading frequency or were acquired by another company. In addition, we detected that for three companies, the Bloomberg ticker had changed over time; in this case, we updated the price series with the new ticker.

Next, we ensured that there was no missing price data for the remaining companies in the 30 days before and after their commitment, target setting, or change from commitment to having a target. Among our sample, 24 companies did not satisfy the criteria and were excluded from the dataset. As a result, our final sample consists of 1,379 firms.

Finally, the SBTi database includes 52 different sectors. We grouped these sectors using the two-digit classification of the International Standard Industrial Classification of All Economic Activities (ISIC) and obtained a list of 23 different aggregated sectors across our sample.

B Appendix. Augmented Dickey-Fuller Unit Root Test

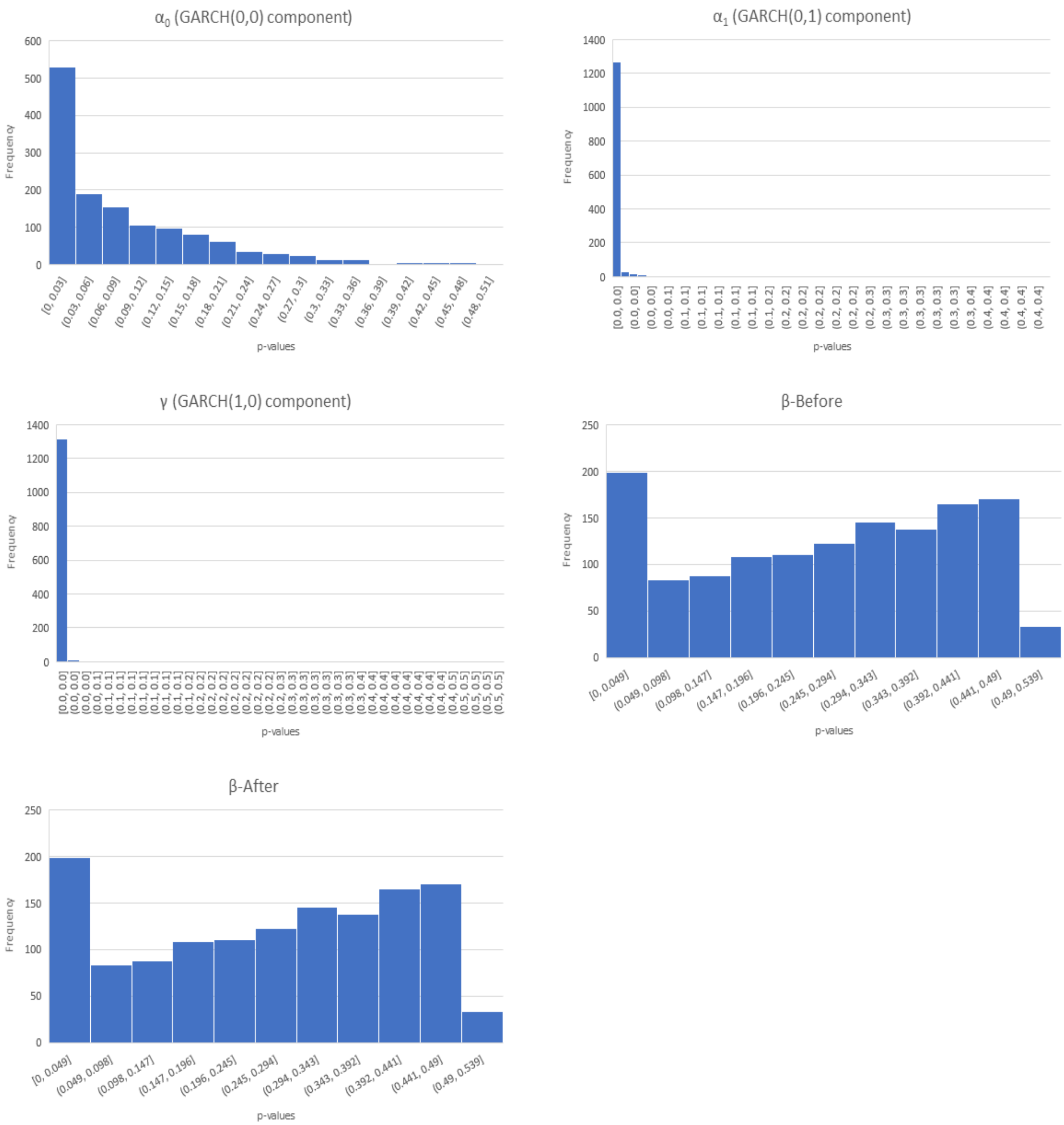
Figure B.1: Dickey-Fuller Statistic Histogram



The critical value at the 1 percent confidence level is 2.567.
Source: Authors elaboration based on SBTi (2022)

C Appendix. P-values for all Parameters in the GARCH with Trend Models

Figure C.2: P-values Histogram



Source: Authors elaboration based on SBTi (2022)