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ESG IN THE ENERGY SECTOR: A DUE DILIGENCE CHECKLIST AND A REGRESSION STUDY

A thesis by

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Abstract

The current diploma thesis focuses on the Environmental, Social, and Governance (ESG) metrics and performance of companies specializing in the Energy Sector. The aim is to assess the importance of these metrics and their impact on the function of the energy firms. For achieving this goal, various policies and methodologies are examined. Policies are studied regarding the targets they pose and the procedures they suggest for reaching them, and methodologies are analyzed concerning the assessment techniques they propose for evaluating a firm's ESG performance. The impact of the ESG scores on the firms' well-being is investigated through mathematical analysis, aiming to define and interpret the relationships between the firm's financial and ESG performance.

The first part of the thesis covers the creation of a due diligence checklist for assessing the ESG practices of companies active in the Energy Sector. The checklist complements the ESG-rating toolkit of the Decision Support Systems (DSS) Laboratory of the National Technical University of Athens. The checklist relies on several widely recognized reporting guidelines, rating tools, and standards, as well as established frameworks and policies. The methodologies include, among others, the GRI, GHG Protocol, SASB standards, and the Refinitiv ESG metrics.

The second part of the thesis attempts to quantify the impact of the ESG scores on the market value and the risk of US energy firms through regression analysis for 122 firms for the 2015-2020 period. The basic theory regarding regression models is presented and explained, and two separate models are constructed. The first model employs the annual revenues and the leverage of the firms, along with their ESG scores, for assessing their market value. The second model employs the return on assets and the leverage of the firms, along with their ESG scores, for estimating their annual risk. Moreover, two alternative dummy models are introduced, replacing the ESG score with two ESG dummies. The results of all models are interpreted to determine the significance of the ESG metrics.

Keywords: ESG, Sustainability, Regression analysis, Market value, Risk

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Εκτενής περίληψη

ESG στον Ενεργειακό Τομέα: Κριτήρια Ελέγχου και Μελέτη Παλινδρόμησης

Η παρούσα διπλωματική εργασία επικεντρώνεται στα κριτήρια αξιολόγησης ESG και στις επιδόσεις εταιρειών που ειδικεύονται στον ενεργειακό τομέα πάνω στο δείκτη. Σκοπός είναι να αξιολογηθεί η αξία των μετρήσεων ESG και η επίδρασή τους στη λειτουργία των ενεργειακών επιχειρήσεων.

Το πρώτο μέρος της εργασίας αφορά στη δημιουργία μιας λίστας ελέγχου για πρακτικές πάνω στα κριτήρια ESG, για εταιρείες που δραστηριοποιούνται στον ενεργειακό τομέα. Συγκεκριμένα, περιλαμβάνονται οι κίνδυνοι της αναποτελεσματικής αξιολόγησης, καθώς και η συλλογή και κριτική επιλογή κριτηρίων από υπάρχουσες οδηγίες για τη σύνταξη αναφορών, από εργαλεία βαθμολόγησης και αξιολόγησης πρακτικών και από πρότυπα που έχουν αναπτυχθεί πάνω σε θέματα Βιωσιμότητας. Στο τέλος αυτής της ενότητας, με βάση τα υπάρχοντα πρότυπα που αναλύθηκαν, δημιουργείται μια λίστα ελέγχου που εφαρμόζεται συγκεκριμένα σε εταιρείες του ενεργειακού τομέα και συμπληρώνει το εργαλείο που έχει δημιουργήσει το Εργαστήριο Συστημάτων Αποφάσεων και Διοίκησης της Σχολής Ηλεκτρολόγων Μηχανικών και Μηχανικών Υπολογιστών του Εθνικού Μετσόβιου Πολυτεχνείου για την αξιολόγηση ενός οργανισμού πάνω στα κριτήρια ESG.

Το δεύτερο μέρος αφορά σε μια ανάλυση παλινδρόμησης, η οποία εξετάζει την επίδραση της βαθμολογίας ESG στις εταιρείες που δραστηριοποιούνται στον ενεργειακό τομέα. Συγκεκριμένα, διερευνάται η επιρροή του ESG στην αξία και το ρίσκο της εταιρείας. Στην ενότητα αυτή παρουσιάζεται η βασική θεωρία των μοντέλων πολλαπλής γραμμικής παλινδρόμησης και δημιουργούνται τέσσερα παλινδρομικά μοντέλα με στόχο τον προσδιορισμό της σχέσης μεταξύ της βαθμολογίας ESG και της αξίας/του ρίσκου των εταιρειών που δραστηριοποιούνται στον ενεργειακό τομέα. Εξετάζεται η περίοδος 2015 έως 2020, και λαμβάνονται δεδομένα από ενεργειακές εταιρείες που έχουν εισαχθεί στο Χρηματιστήριο της Νέας Υόρκης.

Εισαγωγή

Ολοένα αυξανόμενα στοιχεία δείχνουν ότι η αξία μιας εταιρείας επηρεάζεται από παράγοντες που δεν συνδέονται με την οικονομική της απόδοση. Μέσα στα τελευταία 25 χρόνια, τα άυλα περιουσιακά στοιχεία, όπως η εταιρική κοινωνική ευθύνη, η φήμη και η πνευματική ιδιοκτησία αναδείχθηκαν ως η κορυφαία κατηγορία περιουσιακών στοιχείων. Ειδικότερα, το 2020, τα άυλα περιουσιακά στοιχεία κατείχαν το 90% της αξίας του δείκτη S&P500 του Χρηματιστηρίου.

Για αυτόν το σκοπό εξετάζονται οι έννοιες της Βιώσιμης Ανάπτυξης, της Εταιρικής Κοινωνικής Ευθύνης, και των κριτηρίων ESG. Ο επικρατέστερος ορισμός της Βιώσιμης Ανάπτυξης αναφέρει ότι «Βιώσιμη Ανάπτυξη είναι η ανάπτυξη που ανταποκρίνεται στις ανάγκες του παρόντος χωρίς να υπονομεύει την ικανότητα των μελλοντικών γενεών να καλύψουν τις ανάγκες τους». Αποτελείται από τρείς αλληλοσυνδεόμενους άξονες, την Κοινωνία, την Οικονομία και το Περιβάλλον.

Η Βιωσιμότητα δίνει έμφαση σε κοινές πράξεις για όλους τους τομείς της κοινωνίας. Η Εταιρική Κοινωνική Ευθύνη εστιάζει σε πρακτικές των επιχειρήσεων και των οργανισμών για την προώθηση της Βιώσιμης Ανάπτυξης. Η Εταιρική Κοινωνική Ευθύνη αποτελεί την εθελοντική δέσμευση των επιχειρήσεων να συμβάλλουν στη Βιώσιμη Ανάπτυξη κάθε οντότητας που επηρεάζεται από τις δραστηριότητές τους. Στο πλαίσιο αυτής, οι οργανισμοί θα πρέπει να αναπτύσσουν κατάλληλες επιχειρησιακές στρατηγικές.

Ο δείκτης ESG χρησιμοποιείται ως εργαλείο για την ποσοτικοποίηση και αξιολόγηση των επιχειρησιακών πρακτικών που σχετίζονται με το περιβάλλον, την κοινωνία και την εταιρική διακυβέρνηση. Αντικατοπτρίζει την ικανότητα των επιχειρήσεων να παράγουν αξία, να διαχειρίζονται τους κινδύνους και να εξελίσσονται. Τα περιβαλλοντικά κριτήρια του δείκτη ESG σχετίζονται με την αποτελεσματική χρήση των πόρων μιας εταιρείας. Τα κοινωνικά κριτήρια αναφέρονται στα μέτρα που λαμβάνονται από τον οργανισμό για την ευημερία της κοινωνίας. Τα κριτήρια εταιρικής διακυβέρνησης αναφέρονται στις ενέργειες στις οποίες προβαίνει ο οργανισμός για τη διασφάλιση της διαφάνειας και της ανεξαρτησίας του.

Στη συνέχεια, αναλύεται το ρίσκο που οι οργανισμοί αντιμετωπίζουν λόγω της μη συμμόρφωσης σε πρακτικές βιωσιμότητας, καθώς και οι ευκαιρίες που οι νέες αυτές συνθήκες προσφέρουν. Το Παγκόσμιο Οικονομικό Φόρουμ (World Economic Forum) αξιολογεί ετησίως τις απειλές και τις επιπτώσεις τους στις χώρες και στους τομείς επιχειρήσεων, για τα επόμενα δέκα χρόνια. Το 2021, οι ακραίες καιρικές συνθήκες, η αδυναμία λήψης κατάλληλων δράσεων για το περιβάλλον και οι μεταδοτικές ασθένειες είναι μερικοί από τους πιο σημαντικούς παράγοντες που έχουν εντοπιστεί. Αντίστοιχα, η KPMG έχει εντοπίσει κινδύνους και ευκαιρίες, που ονομάζει «μεγαδυνάμεις» και που θα αποτελέσουν την κινητήρια δύναμη της επιχειρηματικής αλλαγής έως το 2035. Οι «μεγαδυνάμεις» περιλαμβάνουν την κλιματική αλλαγή, την ενέργεια και τα καύσιμα, την αύξηση πληθυσμού κ.α.

Σήμερα, έχουν ήδη γίνει σημαντικά βήματα προς τη Βιωσιμότητα. Χαρακτηριστικά παραδείγματα είναι ότι περισσότερες από 130 χώρες έχουν δεσμευτεί να επιτύχουν το στόχο των μηδενικών ρύπων μέσα στα επόμενα χρόνια, οι επενδύσεις που σχετίζονται με τη Βιωσιμότητα αυξήθηκαν στις ΗΠΑ κατά 42% μεταξύ του 2018 και του 2020 και το γεγονός ότι το 70% των στοιχείων του ενεργητικού στις ΗΠΑ δεν μπορεί να αναλυθεί χωρίς να γίνει αναφορά σε άυλα περιουσιακά στοιχεία ESG. Παρατηρείται ότι οι Ηνωμένες Πολιτείες και η Ευρώπη προηγούνται σε ενέργειες για την προώθηση και εφαρμογή πρακτικών Βιωσιμότητας.

Με στόχο την προώθηση της βιώσιμης ανάπτυξης, οι κυβερνήσεις έχουν θεσπίσει κατάλληλα πλαίσια και πολιτικές σε παγκόσμιο και κρατικό επίπεδο. Μερικές από τις πιο κρίσιμες πολιτικές, οι οποίες εξετάζονται στο πλαίσιο αυτής της ενότητας, αποτελούν οι ακόλουθες:

- Οι Στόχοι Βιώσιμης Ανάπτυξης
- Η Ευρωπαϊκή Πράσινη Συμφωνία
- Παγκόσμιο Σύμφωνο των Ηνωμένων Εθνών
- COP3, COP21 και COP26

- Οδηγία της ΕΕ για την υποχρεωτική υποβολή αναφορών
- Το πλαίσιο της ΕΕ για το κλίμα και την ενέργεια
- Ο φόρος άνθρακα του Καναδά

Κριτήρια Ελέγχου

Στην ενότητα αυτή εισάγεται ένα σύνολο κατευθυντήριων γραμμών και δεικτών που θα χρησιμοποιηθούν ως λίστα ελέγχου για την αξιολόγηση των εταιρειών στον ενεργειακό τομέα, αναφορικά με τη Βιωσιμότητα.

Είναι εμφανές ότι οι παραδοσιακοί, χρηματοοικονομικοί δείκτες απόδοσης (KPIs) δεν επαρκούν για την παρακολούθηση της εξέλιξης ενός οργανισμού. Καθώς οι ευκαιρίες και οι κίνδυνοι που σχετίζονται με το ESG γίνονται σημαντικό μέρος του άυλου κεφαλαίου μιας εταιρείας, οι μετρήσεις ESG τείνουν να συμπληρώνουν τους παραδοσιακούς δείκτες.

Παρόλα αυτά, μια κοινή πρακτική που έχει εντοπιστεί σε εκθέσεις βιωσιμότητας είναι ο καθορισμός και η αξιολόγηση ασαφών στόχων. Παρόλο που οι οργανισμοί αναγνωρίζουν την ανάγκη για ενέργειες προώθησης της Βιωσιμότητας, μόνο ένα πολύ μικρό ποσοστό αυτών ευθυγραμμίζει τη στρατηγική και τους στόχους του με τις συγκεκριμένες ενέργειες για την αποφυγή της περιβαλλοντικής κρίσης. Ως αποτέλεσμα προκύπτουν τα φαινόμενα Greenwashing και Bluewashing. Το Greenwashing είναι η πρακτική χρήσης μάρκετινγκ με σκοπό να πείσει ψευδώς το αγοραστικό κοινό ότι τα προϊόντα, οι υπηρεσίες, οι στόχοι και οι πολιτικές ενός οργανισμού είναι φιλικά προς το περιβάλλον. Το Bluewashing, είναι η πρακτική της προβολής ψευδούς εικόνας ευθυγράμμισης των οργανισμών με κοινωνικά υπεύθυνες πρακτικές.

Στη συνέχεια της ενότητας εντοπίζονται υπάρχουσες οδηγίες για σύνταξη αναφορών, εργαλεία βαθμολόγησης και αξιολόγησης πρακτικών και πρότυπα που έχουν αναπτυχθεί πάνω σε θέματα Βιωσιμότητας. Από αυτά επιλέγονται να αναλυθούν οι μεθοδολογίες GRI, GHG Protocol, SASB Standards, CSA, ATHEX ESG Index και Refenitiv ESG. Για καθένα από αυτά έχουν συλλεχθεί κριτήρια που αναφέρονται πρωτίστως σε οργανισμούς που δραστηριοποιούνται στον ενεργειακό τομέα.

Με βάση τα κριτήρια αυτά, και τις πολιτικές που εξετάστηκαν στην εισαγωγή, δημιουργείται μία λίστα κριτηρίων ελέγχου για τις επιχειρήσεις του ενεργειακού τομέα, η οποία συμπληρώνει το εργαλείο που έχει δημιουργήσει το Εργαστήριο Συστημάτων Αποφάσεων και Διοίκησης της Σχολής Ηλεκτρολόγων Μηχανικών και Μηχανικών Υπολογιστών του ΕΜΠ για την αξιολόγηση ενός οργανισμού πάνω στα κριτήρια ESG. Τα κριτήρια ακολουθούν τη δομή του εργαστηρίου, και είναι προσεχτικά επιλεγμένα ώστε να μην υπάρχουν επικαλύψεις με τα γενικά κριτήρια ESG που έχει θέσει το Εργαστήριο και τα οποία ελέγχονται για όλες τις εταιρείες, ανεξαρτήτως τομέα.

Η λίστα αποτελείται από τους ακόλουθους ελέγχους:

- Έχει λάβει η εταιρεία πρόστιμα για μη συμμόρφωση με ενεργειακούς κανονισμούς;
- Έχουν αποτελέσει ζήτημα αντιπαράθεσης οι επιπτώσεις των εργασιών της εταιρείας στους φυσικούς πόρους;
- Είναι αποδεκτές οι άμεσες και οι ακούσιες διαρροές πετρελαίου και άλλων υδρογονανθράκων σε σύγκριση με το μέσο όρο της βιομηχανίας;
- Αναφέρει η εταιρεία πρωτοβουλίες για τη μείωση, την υποκατάσταση ή τη σταδιακή κατάργηση πτητικών οργανικών ενώσεων (VOC) ή σωματιδίων διαμέτρου μικρότερης από δέκα μικρόμετρων (PM10);
- Έχει αναφερθεί μείωση της κατανάλωσης ενέργειας ως αποτέλεσμα πρωτοβουλιών διατήρησης και απόδοσης; Εάν ναι, είναι αποδεκτό το ποσό σε σύγκριση με αυτό άλλων εταιρειών ίδιου μεγέθους του κλάδου;
- Έχει θέσει η εταιρεία στόχους και πολιτικές για την ενεργειακή απόδοση;
- Έχει η εταιρεία δημόσια δέσμευση για την παύση χρήσης ορυκτών καυσίμων;
- Αναπτύσσει η εταιρεία προϊόντα ή τεχνολογίες για καθαρή, ανανεώσιμη ενέργεια (όπως αιολική, ηλιακή, υδροηλεκτρική και γεωθερμική και ενέργεια από βιομάζα);
- Είναι αποδεκτή η ποσότητα της παραγόμενης ενέργειας από ανανεώσιμες πηγές ως ποσοστό της συνολικής παραγόμενης ενέργειας σε σύγκριση με αυτήν των εταιρειών ίδιου μεγέθους του κλάδου;

- Είναι αποδεκτή η ποσότητα ανανεώσιμων πηγών ενέργειας που αγοράζεται ως ποσοστό της συνολικής παραγόμενης ενέργειας σε σύγκριση με αυτήν των εταιρειών ίδιου μεγέθους του κλάδου;
- Είναι αποδεκτή η ποσότητα της ανανεώσιμης ενέργειας που πωλείται ως ποσοστό της συνολικής παραγόμενης ενέργειας σε σύγκριση με αυτή των εταιρειών ίδιου μεγέθους του κλάδου;
- Είναι αποδεκτό το ποσοστό απώλειας ενέργειας στο δίκτυο ή κατά τη μεταφορά σε σύγκριση με αυτό των εταιρειών ίδιου μεγέθους του κλάδου;
- Είναι αποδεκτή η κατανάλωση ενέργειας εκτός της εταιρείας από τη δραστηριότητά της (π.χ. χρήση πωλούμενων προϊόντων, απόβλητα που παράγονται σε εργασίες κ.λπ.), σε σύγκριση με αυτή άλλων εταιρειών του κλάδου;
- Έχει θέσει η εταιρεία στόχους/πολιτικές για τη διαχείριση/μείωση των αερίων του θερμοκηπίου;
- Συντάσσει η εταιρεία εκθέσεις σχετικές με τα αέρια του θερμοκηπίου;
- Είναι αποδεκτό το ποσό των συνολικών εκπομπών "Scope 1" σε σύγκριση με αυτό των εταιρειών ίδιου μεγέθους του κλάδου;
- Είναι αποδεκτό το ποσό των συνολικών εκπομπών "Scope 2" σε σύγκριση με αυτό των εταιρειών ίδιου μεγέθους του κλάδου;
- Είναι αποδεκτό το ποσό των συνολικών εκπομπών "Scope 3" σε σύγκριση με αυτό των εταιρειών ίδιου μεγέθους του κλάδου;
- Είναι αποδεκτές οι εκπομπές αερίων του θερμοκηπίου που είτε καλύπτονται από το Πρωτόκολλο του Κιότο (CO2, CH4, N2O, HFCs, PFCs, SF6) είτε όχι (π.χ. CFC, NOx,) με βάση τους κανονισμούς της χώρας;
- Δημοσιεύει η εταιρεία ξεχωριστή έκθεση Εταιρικής Κοινωνικής Ευθύνης/ Βιωσιμότητας;
- Εκπαιδεύει η εταιρεία τους υπαλλήλους της σε περιβαλλοντικά και ενεργειακά θέματα;
- Η έκθεση Εταιρικής Κοινωνικής Ευθύνης/ Βιωσιμότητας, εάν υπάρχει, εξετάζεται από εξωτερικούς ελεγκτές;
- Δημοσιεύεται η έκθεση Εταιρικής Κοινωνικής Ευθύνης/ Βιωσιμότητας, εάν υπάρχει, σύμφωνα με τις κατευθυντήριες γραμμές του GRI;

- Έχει εντοπίσει η εταιρεία σημαντικούς μακροπρόθεσμους αναδυόμενους κινδύνους που σχετίζονται με την ενέργεια;
- Έχει πραγματοποιήσει η εταιρεία περιβαλλοντικές επενδύσεις – δαπάνες για τη μείωση των μελλοντικών κινδύνων που σχετίζονται με την ενέργεια ή την αύξηση μελλοντικών ευκαιριών;
- Εφαρμόζει ο οργανισμός το TCFD ή οποιοδήποτε άλλο καθιερωμένο πλαίσιο για τη διαχείριση κινδύνων και ευκαιριών που σχετίζονται με την ενέργεια;

Μελέτη Παλινδρόμησης

Στην ενότητα αυτή εξετάζεται η συσχέτιση των κριτηρίων ESG με την αξία και το ρίσκο εταιρειών του ενεργειακού τομέα. Για αυτό το σκοπό, δημιουργείται μια βάση δεδομένων με 122 ενεργειακές εταιρείες που έχουν εισαχθεί στο Χρηματιστήριο της Νέας Υόρκης (NYSE) και έχουν λάβει τουλάχιστον μια βαθμολογία ESG έως το 2020. Τα δεδομένα συλλέγονται από την πλατφόρμα Refinitiv Eikon της Thomson Reuters για τη περίοδο 2015-2020. Τα μοντέλα κατασκευάζονται για την περίοδο 2015-2019, ενώ το 2020 χρησιμοποιείται για αξιολόγηση των εκ των υστέρων προβλέψεων των μοντέλων.

Προσδιορίζεται η μεθοδολογία της παλινδρόμησης που ακολουθήθηκε, δηλαδή το μοντέλο της γραμμικής παλινδρόμησης, ο υπολογισμός των συντελεστών παλινδρόμησης με τη μέθοδο των Ελαχίστων Τετραγώνων, η μελέτη συσχέτισης των μεταβλητών, οι μετρικές του μοντέλου (συντελεστής προσδιορισμού R^2 και σφάλματα των μεταβλητών), η πολυσυγγραμμικότητα, η μελέτη υπολειμμάτων (για κανονικότητα και ετεροσκεδαστικότητα), και η αξιολόγηση των εκ των υστέρων προβλέψεων του μοντέλου.

Στη συνέχεια, δημιουργούνται τα μοντέλα. Το πρώτο μοντέλο επικεντρώνεται στην αξία της εταιρείας και την επιρροή του ESG σε αυτήν. Η αξία εκφράζεται από την κεφαλαιοποίηση της εκάστοτε εταιρείας στο χρηματιστήριο, η οποία προκύπτει ως το γινόμενο του αριθμού των μετοχών της και της τιμής της μετοχής. Ο φυσικός λογάριθμος της κεφαλαιοποίησης αποτελεί την εξαρτημένη μεταβλητή του μοντέλου. Ως ανεξάρτητες μεταβλητές, χρησιμοποιούνται η βαθμολογία ESG, ο φυσικός λογάριθμος των ετήσιων εσόδων και η χρηματοοικονομική μόχλευση των εταιρειών, εκφρασμένη ως ο λόγος του συνολικού χρέους προς τα συνολικά περιουσιακά στοιχεία της επιχείρησης. Γίνονται οι κατάλληλοι έλεγχοι και παρατηρείται ότι το μοντέλο έχει πολύ καλή ικανότητα πρόβλεψης. Συμπεραίνεται ότι το μοντέλο προσδιορίζει ότι η αύξηση της βαθμολογίας ESG κατά μια ποσοστιαία μονάδα οδηγεί σε αύξηση της απόλυτης αξίας κατά 1.73%, διατηρώντας σταθερές τις άλλες δύο ανεξάρτητες μεταβλητές. Για μια εταιρεία μέσης αξίας της τάξης των $2.041 δις. (για το προς μελέτη δείγμα), η αύξηση του 1.73% αντιστοιχεί σε απόλυτη αύξηση της αξίας κατά $35.2 εκ.

Εν συνεχεία, εκτιμιέται ένα εναλλακτικό μοντέλο το οποίο αντικαθιστά τη μεταβλητή ESG με τις εικονικές μεταβλητές HSD και LSD. Η HSD λαμβάνει την τιμή 1 όταν τουλάχιστον δυο εκ των τριών επιμέρους βαθμολογιών ESG (αναφορικά Environmental, Social, Governance) είναι άνω του 0.75, αλλιώς λαμβάνει την τιμή 0. Αντίστοιχα, η LSD λαμβάνει τη μονάδα όταν τουλάχιστον δυο εκ των τριών επιμέρους βαθμολογιών ESG είναι κάτω του 0.25, ειδάλλως μηδενίζεται. Ομοίως με προηγουμένως, γίνονται οι κατάλληλοι έλεγχοι και παρατηρείται ότι το μοντέλο έχει πολύ καλή ικανότητα πρόβλεψης. Το μοντέλο συμπεραίνει πως όταν μια εταιρεία καταφέρει να υπερβεί το 75% σε τουλάχιστον δύο επιμέρους βαθμολογίες ESG, η αξία της υπερδιπλασιάζεται (142%), ενώ αντιθέτως, όταν τουλάχιστον δύο επιμέρους βαθμολογίες πέσουν κάτω από 25% η αξία της μειώνεται κατά 21.2%.

Το δεύτερο μοντέλο εστιάζει στο ρίσκο που αντιμετωπίζει η εταιρεία και την επιρροή του ESG σε αυτό. Το εταιρικό ρίσκο υπολογίζεται μέσω της μελέτης των διακυμάνσεων της τιμής της μετοχής της, οι οποίες είτε ωφελούν είτε βλάπτουν της εταιρεία. Η παρούσα μελέτη αξιοποιεί την ετήσια τυπική απόκλιση των λογαριθμικών αποδόσεων των μετοχών των επιχειρήσεων για να προσεγγίσει το ρίσκο τους. Η ημερήσια λογαριθμική απόδοση προκύπτει ως ο φυσικός λογάριθμος του λόγου της τρέχουσας τιμής της μετοχής προς την τιμή της μετοχής της προηγούμενης εργάσιμης ημέρας. Συγκεντρώνοντας όλες τις ημερήσιες αποδόσεις του έτους, δύναται να προσδιοριστεί η τυπική τους απόκλιση, η οποία πολλαπλασιαζόμενη με την τετραγωνική ρίζα του συνόλου των εργασίμων ημερών του έτους δίνει το ετήσιο ρίσκο της εκάστοτε επιχείρησης. Ο φυσικός λογάριθμος αυτού του ρίσκου αποτελεί την εξαρτημένη μεταβλητή του μοντέλου. Ως ανεξάρτητες μεταβλητές, χρησιμοποιούνται η λογαριθμική βαθμολογία ESG, που λαμβάνει αποκλειστικά αρνητικές τιμές, η απόδοση ενεργητικού, που υπολογίζεται ως ο λόγος του καθαρού εισοδήματος προς τα συνολικά περιουσιακά στοιχεία της εταιρείας, και η χρηματοοικονομική μόχλευση, εκφρασμένη ως ο λόγος του συνολικού χρέους προς τα συνολικά περιουσιακά στοιχεία της επιχείρησης. Γίνονται οι κατάλληλοι έλεγχοι και παρατηρείται ότι το μοντέλο έχει ικανοποιητική ικανότητα πρόβλεψης. Το μοντέλο προσδιορίζει ότι η αύξηση της βαθμολογίας κατά 10% οδηγεί σε μείωση του ρίσκου κατά 5.99%, διατηρώντας σταθερές τις άλλες δύο ανεξάρτητες μεταβλητές. Για μια εταιρεία με μέσο ετήσιο ρίσκο της τάξης του 48.97% (για το προς μελέτη δείγμα), η μείωση αυτή αντιστοιχεί σε απόλυτη μείωση του ρίσκου κατά 2.93 ποσοστιαίες μονάδες.

Εν συνεχεία, εκτιμιέται ένα εναλλακτικό μοντέλο το οποίο αντικαθιστά τη μεταβλητή ESG με τις εικονικές μεταβλητές HSD και LSD. Ο υπολογισμός των εικονικών μεταβλητών είναι όμοιος με αυτών του εναλλακτικού μοντέλου εταιρικής αξίας. Το μοντέλο συμπεραίνει πως όταν μια εταιρεία καταφέρει να υπερβεί το 75% σε τουλάχιστον δύο επιμέρους βαθμολογίες ESG, το ρίσκο της μειώνεται κατά 33% (περίπου 16 ποσοστιαίες μονάδες για εταιρεία μέσου ρίσκου) ενώ αντιθέτως, όταν τουλάχιστον δύο επιμέρους βαθμολογίες πέσουν κάτω από 25%, το ρίσκο αυξάνεται κατά 12% (περίπου 6 ποσοστιαίες μονάδες για εταιρεία μέσου ρίσκου).

Συμπεράσματα

Πολιτικές και εργαλεία σχετικά με το ESG είναι ήδη σε ισχύ και σταδιακά δημιουργούνται νέες, βελτιωμένες μεθοδολογίες αξιολόγησής του, αφού, όπως αποδεικνύεται, η δημιουργία εκθέσεων για το ESG και η επίτευξη υψηλών βαθμολογιών επηρεάζουν την αξία και το ρίσκο μίας επιχείρησης. Συμπεραίνεται ότι οι επενδυτές και όλα τα ενδιαφερόμενα μέρη πρέπει να επικεντρωθούν στο ESG ως παράγοντα που επηρεάζει την πορεία της εταιρείας, και που θα συνεχίσει να αναπτύσσεται με ταχείς ρυθμούς τα επόμενα χρόνια.

Λέξεις-κλειδιά: ESG, Βιωσιμότητα, Ανάλυση παλινδρόμησης, Κεφαλαιοποίηση, Κίνδυνος

List of Abbreviations

ESG	Environmental, Social, Governance
CSR	Corporate Social Responsibility
UN	United Nations
US	United States
EU	European Union
KPI	Key Performance Indicator
SDG	Sustainable Development Goals
COPs	Conferences of the Parties
NDC	Nationally Determined Contribution
LTS	Long-Term Strategy
EFRAG	European Financial Reporting Advisory Group
SMEs	Small and Mid-size Enterprises
ETS	Emissions Trading System
GRI	Global Reporting Initiative
GHG	Greenhouse Gas
CSA	Corporate Sustainability Assessment
CDP	Carbon Disclosure Project
TCFD	Task Force on Climate-related Financial Disclosures
WBCSD	World Business Council for Sustainable Development
FI	Financial Institution
BoD	Board of Directors
VOC	Volatile Organic Compounds
DSS	Decision Support Systems
BLUE	Best Linear Unbiased Estimators
OLS	Ordinary Least Squares
SE	Standard Error
VIF	Variance Inflation Factors
NYSE	New York Stock Exchange
JB	Jarque-Bera
MAE	Mean Absolute Error
MSE	Mean Square Error
ROA	Return on Assets
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization

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Contents

1. Introduction

Increasing evidence suggests that a company's market value is affected by factors other than its financial performance. Within the last quarter-century, intangible assets, such as reputation, intellectual property, and brand value, emerged as the leading asset class. In 2020, in particular, intangible assets were commanding 90% of the S&P500 market value (Ocean Tomo, 2020). Many of these intangibles are related to "sustainability", "environmental, social, and governance", and "corporate social responsibility".

This trend emerges because a company's voluntary actions to manage its environmental and social impact and to increase its positive contribution to society result not only in achieving social goals but also in increasing shareholder value ("doing good by doing well") (Benabou & Tirole, 2010).

1.1 Sustainability

The growing awareness of an imminent ecological crisis has been one of the driving forces around the end of the 20th century. Sustainability as a social, environmental, and economic ideal emerged in the late 1970s and 1980s (Caradonna, 2017). By the 1990s, it had become a familiar term. It was not until the second half of the 20th century, however, that the terms "sustainability" and "sustainable" appeared for the first time in the Oxford English Dictionary (Pisani, 2007).

The most frequently quoted definition of Sustainability states that "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Imperatives, 1987).

Sustainability nowadays has become a popular topic, prompting governments, communities, businesses, and individuals to implement various new measures to survive and grow. Sustainable development centers around three connected dimensions, the environment, the economy, and society. Decision-makers must not only be aware of these dimensions, but also be constantly mindful of their relationships, complementarities, and trade-offs (see Figure 1) to maintain and promote Sustainability (Mensah, 2019).

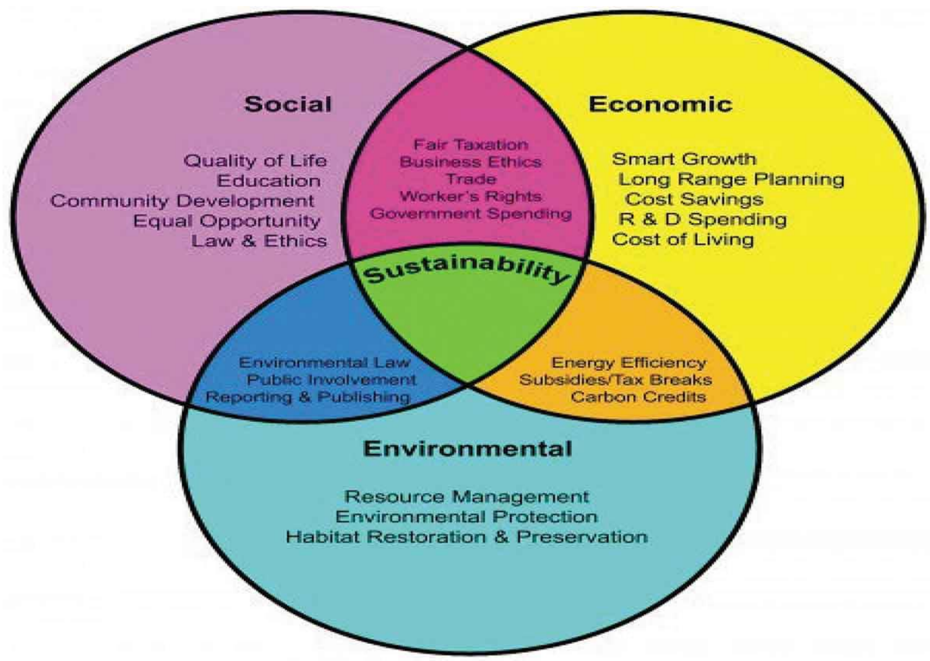


Figure 1 Relationships among social, environmental, and economic Sustainability (Mensah, 2019).

1.2 Corporate Social Responsibility

In 1953, the first book on Corporate Social Responsibility (CSR) was published (Bowen, 1953), remarking the importance of the companies' moral behavior towards society and the relevance of ethical behavior towards stakeholders. Since then, the topics of "Corporate Social Responsibility" and "Corporate

Sustainability" have received much attention, with companies creating departments and functions to address them and academics building scientific disciplines and courses on the topics (Taticchi & Demartini, 2021).

While Sustainability emphasizes a common agenda for all sectors of society, CSR focuses on the corporate practices that promote sustainable development. CSR is the voluntary commitment of businesses to contribute to the sustainable development of every entity influenced by their activities.

CSR centers around the same pillars as Sustainability; the economy, the society, and the environment. Through CSR, the companies define criteria and actions to influence their environment and work towards human rights, labor rights, environmental responsibility, and anti-corruption (Höllerer, 2012).

As a result, the traditional approach of businesses, focused primarily on calculating the return on investments, is rapidly changing. While CSR by definition refers to voluntary measures, investors' and buyers' behaviors prove that organizations will have to actively contribute in order to grow.

CSR is not a theoretical concept but an analytical business strategy with precisely defined steps. A CSR strategy may include the following (Galbreath, 2009):

- Awareness and training
- Stakeholder mapping and analysis
- Sustainability assessment that identifies strengths and areas for improvement
- Comprehensive strategy design for each one of the three pillars
- Activation programs
- Results measuring and reporting

1.3 Environmental, Social, Governance

Environmental, social and corporate governance (ESG) metrics have emerged from Sustainability as specific and essential factors that reflect the companies' ability to generate value, manage risks, and evolve. The value of the ESG metrics is evident by their investment performance and the increased client demand towards sustainable investment practices.

The ESG index is a quantitative indicator of the evaluation and comparison of companies based on environmental, social, and corporate governance criteria.

The environmental criteria relate to the efficient utilization of a company's resources. For example, the indicator can refer to the company's energy footprint and the undertaken initiatives to reduce the energy consumption.

The social criteria refer to the measures taken by the organization for the well-being of society. For example, they may refer to the organization's relationships with suppliers and customers, the workforce management, and the working conditions.

The corporate governance criteria refer to the actions taken by the organization to ensure its transparency and independence. They relate to factors such as the decision-making methods, the adherence to the regulatory framework, and the satisfaction of the interested parties.

In annual surveys asking institutional investors to rate the characteristics of a company that they respect, "ethical business practices" have surpassed categories such as "strong management"(Hill, 2020). The importance of ESG practices is also supported by numerous researches, which conclude that ESG has implications on risk and return (Limkriangkrai et al., 2017, Maiti, 2021, Sassen et al., 2016). An analysis of the effect of the ESG practices on risk and return is presented in Chapter 3.

1.4 Sustainability risks and opportunities

In order to achieve sustainable development, actions must be implemented at the international, national, community, and individual levels. The significant sustainability challenges are summarized by the United Nations' (UN's) Sustainable Development Goals (see Section 1.6.1). Following the UN's call for action, an increasing number of companies are measuring, disclosing, and managing sustainability risks and opportunities.

The World Economic Forum annually assesses the negative impact of threats for countries and industries within the next ten years. The "Global Risks Report" relies on the "Global Risks Perception Survey", completed by over 650 members of the World Economic Forum's diverse leadership communities (World Economic Forum, 2021).

In the 2021 report, extreme weather, climate action failure, and human-led environmental damage were among the highest likelihood risks of the next ten years. Among the highest-impact risks of the next decade, infectious diseases are in the top spot, followed by climate action failure and weapons of mass destruction (see Figure 2and Figure 3).

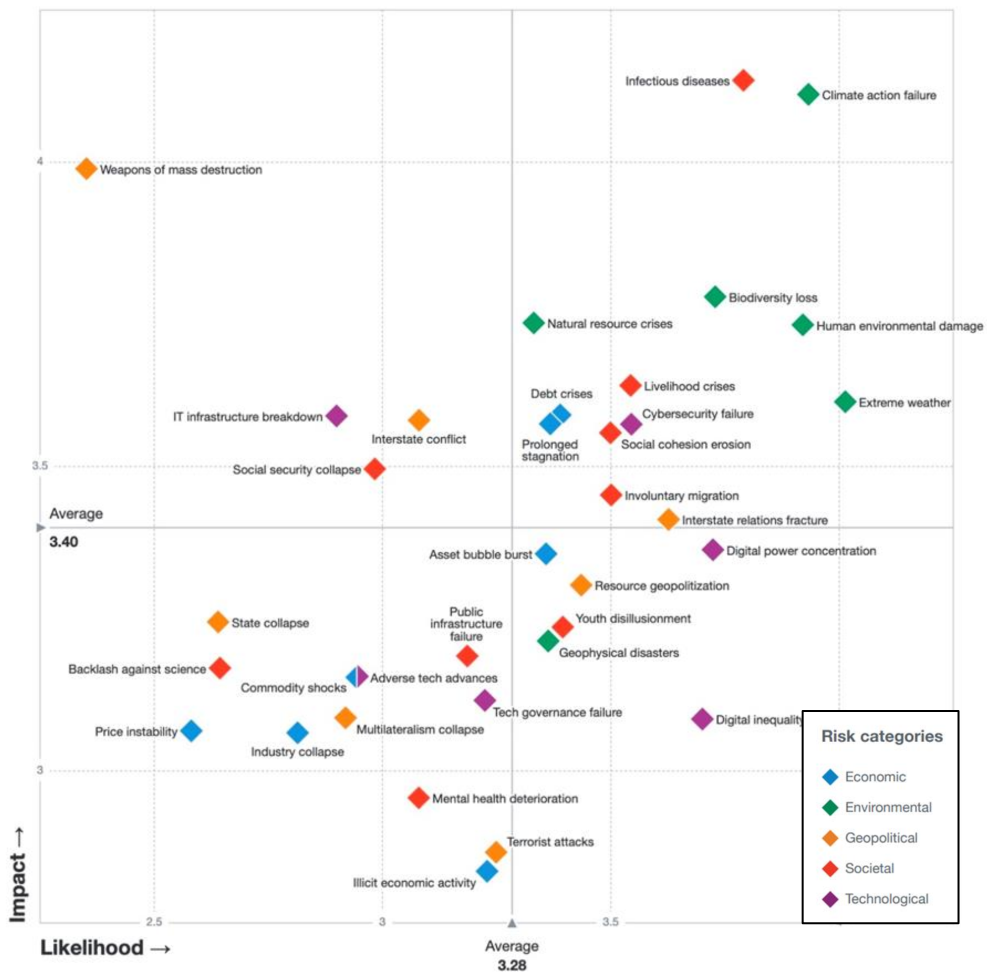


Figure 2 Likelihood and Impact diagram for future threats to Sustainability (World Economic Forum, 2021)**.**

Figure 3 Top risks to Sustainability by likelihood and impact (World Economic Forum, 2021)**.**

The responders also rank the most concerning global risks and their drivers (see Figure 4).

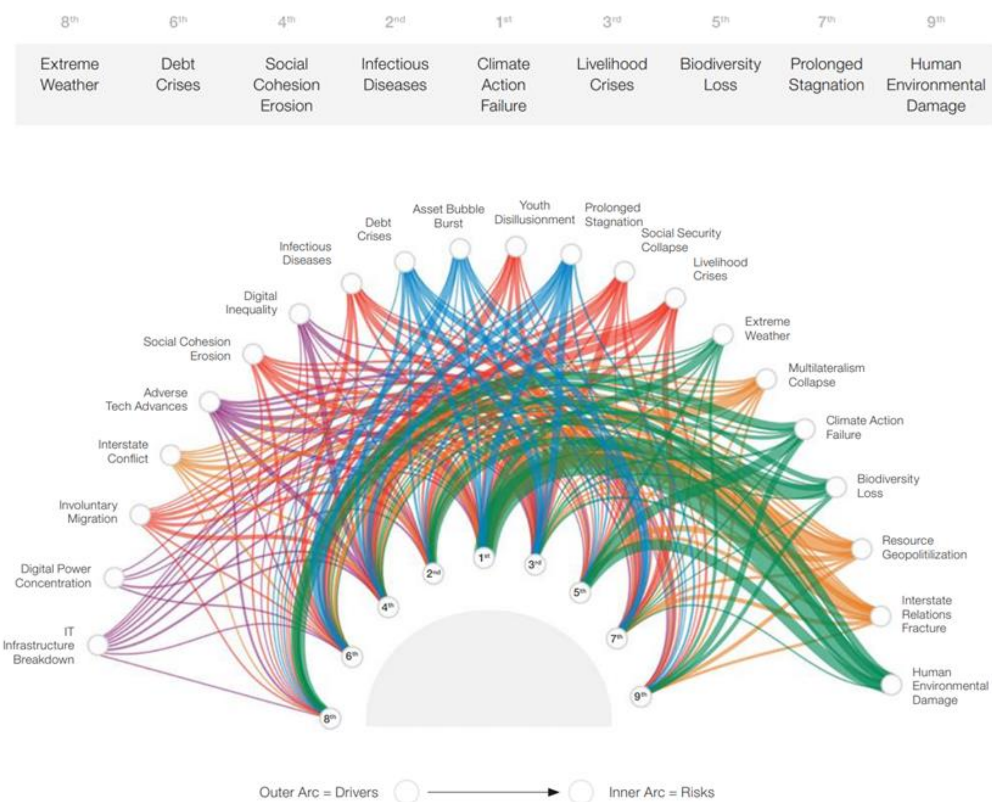


Figure 4 Drivers of the most concerning risks to Sustainability (World Economic Forum, 2021)**.**

Risks and opportunities can also be identified by examining the “megaforces” that drive change. A KPMG analysis has identified several “megaforces” as critical drivers for business change to 2035 and beyond (KPMG International, 2012). These include:

- Climate Change
- Energy & Fuel
- Material Resource Scarcity
- Water Scarcity
- Population Growth
- Urbanization
- Wealth
- Food Security
- Ecosystem Decline
- Deforestation

The “megaforces”, individually, are expected to impact business significantly, but the drivers are also interrelated (Tennant, 2013).

1.5 Current sustainability practices

1.5.1 Sustainability figures

The global efforts for Sustainability greatly affected the environment and society. Indicatively, meaningful results are presented below:

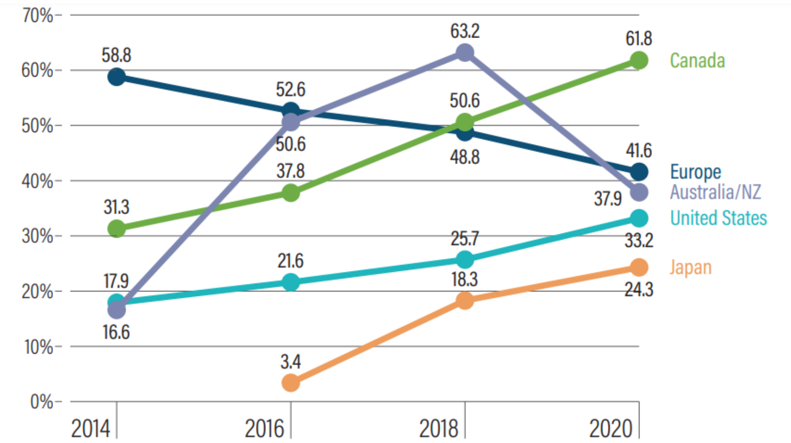
- More than 130 countries have committed to net-zero emissions (Net Zero Tracker, 2022).
- 155 companies signed to urge governments to align the COVID-19 recovery effort with the energy transformation challenges (IISD, 2020).
- The US investments in Sustainability increased by 42%, between 2018 and 2020, from 12tn USD to 17.1tn USD (Global Sustainable Investment Alliance, 2021).

- Sustainable investment assets under management in 2020 made up for 35.9% of total assets under management, compared with 33.4% in 2018 (Global Sustainable Investment Alliance, 2021).
- The United States and Europe represent more than 80% of the global sustainable investing assets from 2018 to 2020 (Global Sustainable Investment Alliance, 2021).
- 70% of US assets cannot be analyzed without referring to ESG intangible assets. Assets tied to reputation, brand, and intellectual property have reached record highs for the S&P 500 companies (Bank of America Merrill Lynch, 2019).
- ESG could have helped avoid 90% of bankruptcies. 15 out of 17 bankruptcies in the S&P 500 between 2005 and 2015 concerned companies with poor Environmental and Social scores five years prior to their bankruptcies (Bank of America Merrill Lynch, 2019).
- An analysis found that more than 500bn USD in market value has been lost from 2014 to 2019 due to ESG controversies (Bank of America Merrill Lynch, 2019).

1.5.2 Sustainability trends

In the last decade, the amount of assets invested in socially responsible investment products and services has increased dramatically. Investors have a growing interest in the ESG practices of companies they invest in, and Millennials and Generation Z are expected to accelerate this trend further (Hill, 2020).

As presented in Figure 5, the proportion of sustainable investing assets to total managed assets has a positive trend. It should be noted that for Europe and Australasia, the results may not be representative due to the significant changes in the way sustainable investment is defined during the last years.



REGION	2014	2016	2018	2020
Europe*	58.8%	52.6%	48.8%	41.6%
United States	17.9%	21.6%	25.7%	33.2%
Canada	31.3%	37.8%	50.6%	61.8%
Australasia*	16.6%	50.6%	63.2%	37.9%
Japan		3.4%	18.3%	24.3%

Figure 5 Proportion of sustainable investing assets relative to total managed assets 2014-2020 (Global Sustainable Investment Alliance, 2021).

Figure 6 is presented for identifying the European trends. The diagram suggests that sustainable funds have a positive trend, with flows in 2020 being almost double those of 2019, at EUR 233bn. (Morningstar, 2021)

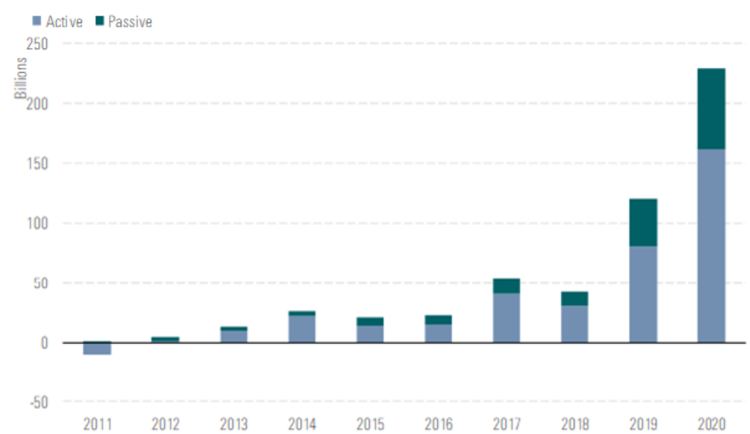


Figure 6 Annual European Sustainable Funds (EUR Billion) (Global Sustainable Investment Alliance, 2021).

1.6 Sustainability-related frameworks and policies

Aiming to promote sustainable development, governments have established several frameworks and policies. Some of the most critical policies include the following:

- The Sustainable Development Goals
- EU's Green Deal
- UN Global Compact
- COP21 and COP26
- EU's Directive on Mandatory Reporting
- EU's Climate and Energy Framework
- Canada's Carbon Tax

The frameworks are discussed below.

1.6.1 Sustainable Development Goals

The United Nations Member States adopted 17 Sustainable Development Goals (SDGs) in 2015 for the present and potential peace and prosperity of the people and the planet. These goals, introduced in the context of the 2030 Agenda for Sustainable development, constitute an urgent call for action by all countries for a global partnership (United Nations, 2015). They address the global challenges, including poverty, inequality, climate change, environmental degradation, peace, and justice. The goals are presented in Figure 7.

In order to monitor the SDGs, a yearly ESG progress chart is presented. The chart is a snapshot of global and regional progress towards selected targets under the 17 Goals of the 2030 Agenda for Sustainable Development. The progress chart provides an overview of global and regional trends towards achieving the Sustainable Development Goals and helps readers visualize the progress towards targets and goals based on specific indicators (United Nations, 2021).

Figure 7 UN's Sustainable Development Goals (United Nations, 2015)**.**

1.6.2 EU's Green Deal

Aiming to become the world's first climate-neutral continent by 2050, the European Union presented in 2019 the European Green Deal, an ambitious package of measures aiming to enable European citizens and businesses to benefit from the green transition. The measures are followed by an initial roadmap of policies, including, among others, decreasing emissions, investing in cutting-edge research and innovation, and preserving Europe's natural environment (European Commission, 2019).

In order to deliver the European Green Deal, it is imperative to rethink policies for clean energy supply across the economy, industry, production, consumption, large-scale infrastructure, transport, food and agriculture, construction, taxation, and social benefits. These areas of action are strongly interlinked and mutually reinforcing; thus, it is vital to consider potential trade-offs among economic, environmental, and social objectives.

The Green Deal could be a new EU growth strategy, provided that it is supported by investments in green technologies, sustainable solutions, and new businesses. The public's and other stakeholders' involvement and dedication are critical for safeguarding the well-being and health of the EU citizens and future generations.

The goal of the Green Deal is a just and socially fair transition, aiming to engage all individuals and regions in providing (as presented in Figure 8):

- Fresh air, clean water, healthy soil, and biodiversity
- Renovated, energy-efficient buildings
- Healthy and affordable food
- More public transport
- Cleaner energy and cutting-edge clean technological innovation
- Longer-lasting products that can be repaired, recycled, and reused
- Future-proof jobs and skills training for the transition
- Globally competitive and resilient industry

The new measures are not sufficient, on their own, for achieving the European Green Deal's objectives. In addition to launching new initiatives, the Commission will work with the Member States to ensure that current legislation and policies relevant to the Green Deal are enforced and effectively implemented.

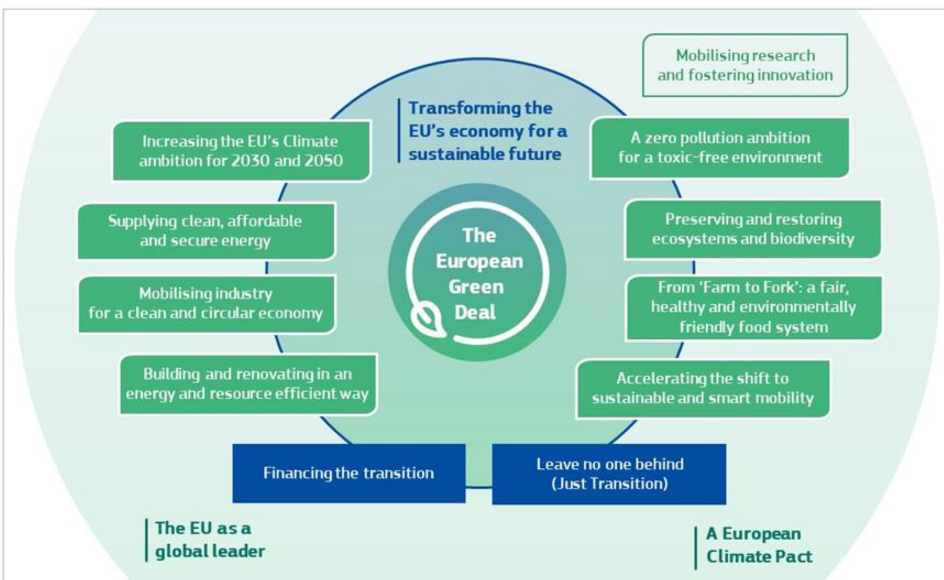


Figure 8 The goals of the European Green Deal (European Commission, 2019).

1.6.3 UN Global Compact

The UN Global Compact is a non-binding United Nations pact that encourages organizations to adopt sustainable and socially responsible policies and report on their implementation, launched in 2000 (UN, 2010). It consists of 10 principles for Corporate Sustainability that refer to human rights, labor, environment, and anti-corruption. The environmental principles are the following:

- Businesses should support a precautionary approach to environmental challenges,
- Businesses should undertake initiatives to promote greater environmental responsibility,
- Businesses should encourage the development and diffusion of environmentally friendly technologies.

1.6.4 COP3, COP21 & COP26

The UN members states participate in global climate summits, called Conferences of the Parties (COPs). The COP assesses the effects of the measures taken by the parties and the progress made towards achieving the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC, 2022).

The COP meets annually unless the Parties decide otherwise. The first COP meeting was held in Germany, in 1995.

COP3

COP3, also known as the Kyoto Protocol, is an international UN treaty, which was adopted in 1997, aiming to engage the United Nations Framework Convention on Climate Change (UNFCCC) by reducing the greenhouse gases emissions (GHG) of the member states, working towards limiting the human impact on global warming. Due to a complex ratification process, the Protocol was enforced in 2005 and is currently signed by 192 countries, with Canada being the only country that has withdrawn from it since 2012.

The following GHG, for which the Protocol is applied, are listed in Annex A.

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)

- Sulfur hexafluoride (SF_6)
- Nitrogen trifluoride (NF_3) (added during the Doha Round)

The Kyoto Protocol, based on the principle of "common but differentiated responsibility and respective capabilities", is only binding for developed nations, admitting that these countries are more responsible for the increased GHG emissions and should, therefore, play a more significant role in remedying them. The countries bound by the Protocol are required to adopt the agreed policies and measures and to report on their progress periodically.

The first commitment lasted from 2008 to 2012 and included 37 industrialized nations. Overall, the imposed measure resulted in a 5% emission reduction from the 1990 levels. In 2012, the Doha Amendment of the Kyoto Protocol was agreed, signifying the beginning of the second commitment period from 2013 to 2020. The amendment was enforced on December 2020 and included a revision of the reported GHG, updates of various articles of the original Protocol, and new commitments for the second commitment period, specifically an at least 18% emission reduction from the 1990 levels by 2020. Negotiations concerning the steps to be taken after the end of the second commitment period in 2020 resulted in adopting the Paris Agreement in 2015, which consists of a separate instrument under the UNFCCC umbrella rather than a Kyoto Protocol amendment.

COP21

In 2015, during the COP21, also referred to as the Paris Agreement, 197 countries pledged to work together to cut greenhouse gas emissions to limit the global average temperature growth below 2 degrees Celsius, preferably to 1.5 degrees Celsius, from the pre-industrial levels (UNFCCC, 2015). It should be noted that climate change has already caused global temperatures to rise about 1°C above the pre-industrial levels (National Centers for Environmental Information (NCEI), 2021).

Countries are legally required to reconvene every five years, starting from 2023, to publicly report their progress in cutting emissions compared to their pledges. While the pledges are voluntary, the countries are legally required to monitor and report their emissions levels and reductions using a universal system.

Specifically, the governments agreed (European Commission, 2015):

- On limiting the global average temperature rise to well below 2 degrees Celsius above pre-industrial levels.
- On limiting the global average temperature rise to 1.5 degrees Celsius.
- On the need for global emissions to reach their peak and start declining as soon as possible, recognizing that this will take longer for developing countries.
- To undertake rapid reductions, utilizing the scientific advancements.
- To come together every five years to set more ambitious targets.
- To report to each other and the public on implementing the targets through a robust transparency and accountability system.
- To strengthen societies' ability to deal with the impacts of climate change.
- To provide support for adaptation to developing countries.

If warming continues to follow the current trend, projections show that the 1.5 °C increase in temperature will be achieved by 2040, while the increase may grow up to 5 °C by the end of the century (WWF, 2018). The increase in temperature would result in melting ice caps and glaciers, leading to a rise of the sea level, which would damage coastal communities and infrastructures. The submergence of entire island countries is also a possibility. Furthermore, the population may be subjected to extreme heat, resulting in the extinction of numerous habitats and species.

It is important to note that, even though climate change is classified as an environmental problem, it impacts all industries. Examples are the agriculture and food industry (as extreme weather conditions heavily affect productivity and capacity), the insurance industry (as companies in this industry pay for the damages caused by extreme weather events and the difficulties inflicted on business activities), the automotive industry (with electric mobility) and the oil and gas sector (the transition to alternative energy sources is accelerated by climate action).

COP26

The COP26 summit in Glasgow, scheduled to take place in 2020 but delayed by a year due to the pandemic, was the fifth anniversary of the Paris Agreement, aiming to ensure that temperature rises limit to 1.5 degrees Celsius (UNFCCC, 2021).

During the Glasgow Climate Pact, all countries agreed to keep the 1.5-degree limit and finalize the outstanding elements of the Paris Agreement.

The outcome includes a series of actions that all Parties are expected to undertake to accelerate their efforts.

Specifically, the results of the COP26 were:

- A more substantial commitment to limit global temperature rise to 1.5 degrees Celsius.
- The introduction of the phrases “phase-down of unabated coal power” and “inefficient fossil fuel subsidies”, as well as “mid-century net-zero”.
- Parties will review their 2030 emission reduction targets in 2022 and, if required, enhance them to align with the Paris Agreement.
- Parties that did not submit new nationally determined contributions (NDCs) are requested to do so before COP27 and propose long-term strategies (LTS) that set out plans to reach net-zero by mid-century.
- Annual Synthesis Reports were decided to be prepared to provide the latest information on the progress of NDCs and LTS.
- The UN Secretary-General will host a Leader Level Summit in 2023 on ambition to 2030.

1.6.5 EU’s Directive on Mandatory Reporting

The European Commission has assigned the European Financial Reporting Advisory Group (EFRAG) to develop EU sustainability reporting guidelines (EFRAG, 2020). Large companies will be required to comply with the guidelines, while Small and Mid-size Enterprises (SMEs) would benefit from a simplified reporting regime. A taskforce convened by the European Commission has already commenced work and published recommendations in March 2021.

The guidelines will consider established global standards, such as GRI and SASB; still, other EU legislations and initiatives must also be considered, such as the Sustainable Finance Disclosure Regulation, the EU Taxonomy, and others.

1.6.6 EU's Climate and Energy Framework

2020 climate and energy package

In 2007, EU leaders decided on a set of targets for climate and energy that was enforced in 2009 (European Commission, 2020).

The 2020 package is a set of laws passed to ensure that the EU meets its climate and energy targets for 2020.

The package sets three key targets:

- 20% cut in greenhouse gas emissions (from 1990 levels)
- 20% of EU energy from renewables
- 20% improvement in energy efficiency

2030 climate and energy framework

In January 2014, the European Commission presented a framework for EU climate and energy policies for the 2020-2030 period (European Council, 2014). The 2030 Framework builds on the experience of, and lessons learned from, the 2020 Climate and Energy package. It also considers the Commission's longer-term perspective set in 2011 in the roadmap for moving to a competitive low carbon economy in 2050, the Energy Roadmap 2050, and the Transport White Paper.

These documents reflect the EU's goal of reducing GHG emissions by at least 80% below 1990 levels by 2050, as part of the effort needed from developed countries as a group. The climate and energy targets to be met by 2030 are (European Council, 2014):

- Reducing greenhouse gas emissions by at least 40% below the 1990 level
- Increasing the share of renewable energy to at least 27%
- Increasing energy efficiency by at least 27%
- Reform of the EU Emissions Trading System (ETS)
- New governance system

1.6.7 Canada's Carbon Tax

In 2019, Canada implemented a carbon tax system to reduce emissions by at least 30% below the 2005 levels by 2030, aiming to reduce the human impact on the environmental crisis (Canada.ca, 2019).

The carbon tax is imposed on the amount of carbon emitted into the atmosphere due to human activity. The carbon emitted is usually in the form of carbon dioxide (CO_2) that is produced from burning fossil fuels.

The goal of a carbon tax is to create incentives for individuals and businesses to reduce their amount of carbon emissions to limit climate change. The carbon tax is also referred to as carbon pricing, price on carbon, greenhouse gas tax (GHG tax), or fuel charge.

2. ESG checklist

Climate change is one of the most critical and perhaps most misunderstood threats organizations face today. While it is widely recognized that continuous greenhouse gas emissions would result in further global warming, that would have implications in the economy and society, predicting the exact time and severity of the physical impacts is challenging. The problem's large-scale and long-term character makes it particularly difficult to solve, especially in the context of economic decision-making. As a result, the effects of climate change may be wrongfully characterized as long-term and, therefore, irrelevant to actions taken today.

Climate change's consequences on organizations, however, are already evident. Governments, societies, organizations, and individuals are already recognizing the consequences and taking action to mitigate the risks.

The efficient use of energy, as well as the use of renewable sources are essential for combating climate change and other key environmental issues, such as air pollution and species' extinctions, and reducing an organization's total environmental footprint. This Chapter aims to introduce a set of guidelines and indices that will be used as a checklist to assess companies in the Energy Sector in terms of Sustainability.

The Energy Sector consists of organizations with a primary activity relating to producing or supplying energy. Energy can have various forms, such as fossil fuel, electricity, heating, cooling, or steam.

Energy can be self-generated or purchased from external sources and can come from renewable sources (such as wind, hydro or solar) or non-renewable sources (such as coal, petroleum, or natural gas). Energy consumption can occur in both upstream and downstream activities associated with a company’s operations. It may refer to the use of the company’s products by the customers and their end-of-life treatment.

2.1 Risks from inefficient reporting

A common practice that has been identified in Sustainability reporting is setting vague targets. In 2017, the World Business Council for Sustainable Development (WBCSD) found that 79% of the analyzed companies acknowledged the SDGs somehow. Only 6%, however, have aligned their strategy and targets with the specific target-level SDG criteria and measured their contributions to key SDGs (World Business Council for Sustainable Development (WBCSD) & Radley Yeldar, 2017). Nowadays, the number has improved significantly, with 30% of the companies discussing target-level ESG information (World Business Council for Sustainable Development (WBCSD) & Radley Yeldar, 2021). The percentage, however, is still not satisfactory. The most common practices of disinformation are greenwashing and bluewashing.

2.1.1 Greenwashing

Greenwashing is the malpractice of using deceptive marketing to persuade the public that an organization’s products, services, goals, and policies are environmentally friendly (Delmas & Burbano, 2011). Greenwashing consumes significant resources in the battle against environmental challenges such as climate change, plastic ocean pollution, air pollution, and global species extinctions.

Greenwashing is a deceptive marketing strategy to garner customers who want to support environmentally conscious companies. It has been found that particularly members of Generation Z are more likely to prefer companies and brands that follow ethical practices (McKinsey & Company, 2018).

Two characteristic cases of Greenwashing concern Volkswagen and Nestlé. Volkswagen has admitted to cheating emission tests by having in various vehicles defect emissions detecting devices (INDEPENDENT, 2015). Nestlé released a statement in 2017 aiming at addressing the growing plastic pollution crisis with vague targets, that was strongly criticized by various environmental groups (Greenpeace, 2018) and, three years later, was named one of the top three world's plastic polluters for the third year in a row, in 2020 (The Guardian, 2020).

2.1.2 Bluewashing

Bluewashing is the malpractice of overstating the organizations' alignment with socially responsible practices. It is similar to Greenwashing but focuses primarily on social and economic factors (Berliner & Prakash, 2015).

Bluewashing was introduced, referring to companies that volunteered to comply with the UN's Global Compact but were not using the UN's ten principles. The color blue originates from the blue logo of the United Nations. Four years after the Global Compact was agreed upon, a study indicated that 33% of the responders indicated that they did not have any policy changes since joining the UN Compact (McKinsey & Company, 2004).

Aware of those false claims of CSR, investors and consumers become reluctant towards Sustainability. In order to promote Sustainability, it is, thus, crucial to use ESG indices that are clearly defined, measurable, and easily validated.

2.2 Sustainability standards

It is evident that traditional, financial key performance indicators (KPIs) are insufficient to monitor an organization's evolution. As ESG-related opportunities and risks are becoming a noteworthy part of a company's intangible capital, ESG metrics tend to complement the traditional indicators.

There is no single model for calculating Sustainability and ESG. In order to measure and assess the company's performance in terms of Sustainability, various methodologies have emerged.

The results of the calculation of the ESG index may be disclosed to the Stock Exchange for the listed companies, as well as voluntarily published in individual reports by companies. It is also necessary to publish the methodology followed and the connection of the criteria with the financial performance of the companies. Using the published data, stakeholders can interpret the results and decide on their accuracy based on the available sources.

Indicatively, the following are presented.

2.2.1 Reporting guidelines for Sustainability – ESG

In response to the need for sustainability reporting, internationally recognized standards have emerged. The guidelines are either used as standalone reporting tools or integrated with rating and reporting indices. Some of the most widely used standards and guidelines are the following:

- Global Reporting Initiative (GRI)
- SASB Standards
- Greenhouse Gas (GHG) Protocol
- Corporate Sustainability Assessment (CSA)
- <IR> Framework
- Task Force on Climate-related Financial Disclosures (TCFD)
- Carbon Disclosure Project (CDP)

2.2.2 Rating & ranking tools for Sustainability – ESG

Several ethical investment rating and ranking tools have emerged to help investors identify the companies that demonstrate good sustainability practices in the last twenty years. Some of them are based on sustainability standards and guidelines, such as the GRI. Indicatively, some of these indices are the following:

- ATHEX ESG index

- Refenitiv
- Dow Jones Sustainability Index
- FTSE4Good
- Morningstar
- Bloomberg
- MSCI
- Sustainalytics

2.2.3 Standards related to Sustainability - ESG

Lastly, a set of standards has been developed to promote Sustainability. These standards focus on management systems, social responsibility, environmental performance, etc. Some of these standards are presented below:

- SA8000
- Accountability1000 (AAlOOO)
- ISO 26000
- ISO l4000

2.3 Selected guidelines and tools

In order to create a checklist to assess the companies that are active in the Energy Sector, established methodologies are examined. The standards that the checklist is primarily based on are presented below. For each of them, a selection of reporting questions that apply to the Energy Sector has been made.

2.3.1 GRI

GRI has created independent international standards for reporting on the impact of organizations on the economy, the environment, and the society. Some data that prove the importance of this standard in ESG reporting are the following:

- There are currently over 10,000 GRI reporters in over 100 countries.
- More than 125 policies across 60 countries and regions refer to GRI.

- 75% of the 250 largest companies in the world use GRI's sustainability reporting framework.

GRI Standards (GRI, 2021) are organized in collections of interconnected guidelines. The GRI 100 refers to standards that apply to every organization. GRI 200, 300, and 400 are topic-specific standards, referring to the economy, the environment, and the society respectively.

All standards have been examined, but the selection that follows is based primarily on GRI 300: Environmental, and more specifically, GRI 302: Energy.

The following GRI reporting guidelines have been selected:

- Total fuel consumption within the organization from non-renewable sources and including fuel types used.
- Total fuel consumption within the organization from renewable sources, including fuel types used.
- Total electricity consumption, heating consumption, cooling consumption and steam consumption.
- Total electricity sold, heating sold, cooling sold and steam sold.
- Total energy consumption within the organization, calculated as the sum of non-renewable and renewable fuel consumed, electricity, heating, cooling and steam purchased for consumption and self-generated electricity, heating, cooling and steam, which are not consumed, minus electricity, heating, cooling and steam sold.
- Energy consumption outside of the organization (e.g., use of sold products, waste generated in operations, business travel etc.).
- Energy intensity ratio for the organization, as the absolute energy consumption by an organization-specific metric, chosen by the organization (e.g., production volume, number of full-time employees, monetary units etc.).
- Amount of reductions in energy consumption achieved as a direct result of conservation and efficiency initiatives, and their types (fuel, electricity, heating, cooling, steam).
- Reductions in energy requirements of sold products and services achieved during the reporting period.

Standards' guidelines:

The following should also be reported:

- Standards, methodologies, assumptions, and/ or calculation tools used.
- The basis for calculating reductions in energy consumption, such as base year or baseline, including the rationale for choosing it.

2.3.2 GHG Protocol

GHG Protocol supplies greenhouse gas accounting standards (World Resources Institute (WRI) et al., 2012). In 2016, 92% of Fortune 500 companies responding to the CDP used GHG Protocol directly or indirectly through reporting standards based on GHG Protocol.

The protocol defines three "scopes" (scope 1, scope 2, and scope 3) for GHG accounting and reporting purposes. Companies shall separately account for and report on scopes 1 and 2 at a minimum (World Resources Institute (WRI) et al., 2012).

Scope 1: Direct GHG emissions

Direct GHG emissions occur from sources owned or controlled by the company, such as emissions from combustion in owned or controlled boilers, furnaces, vehicles, or emissions from chemical production in owned or controlled process equipment.

Scope 2: Electricity indirect GHG emissions

Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.

Scope 3: Other indirect GHG emissions

Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.

The following GHG reporting guidelines have been selected:

- Total scope 1 and 2 emissions independent of any GHG trades such as sales, purchases, transfers, or banking of allowances.
- Emissions data for all six GHGs separately (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) in metric tonnes and in tonnes of CO_2 equivalent.
- Emissions from GHGs not covered by the Kyoto Protocol (e.g., CFCs, NO_x,), reported separately from the scopes.
- Emissions data for direct CO_2 emissions from biologically sequestered carbon (e.g., CO_2 from burning biomass/biofuels), reported separately from the scopes.
- Emissions attributable to own generation of electricity, heat, or steam that is sold or transferred to another organization.
- Emissions attributable to the generation of electricity, heat, or steam that is purchased for re-sale to non-end users.
- Relevant ratio performance indicators (e.g., emissions per kilowatt-hour generated, tonne of material production, or sales).
- An outline of any GHG management/reduction programs or strategies.

Standards' guidelines:

Reported information shall be "relevant, complete, consistent, transparent, and accurate" (World Resources Institute (WRI) et al., 2012). The information should:

- Be based on the best data available at the time of publication while being transparent about its limitations.
- Communicate any material discrepancies identified in previous years.
- Include the company's gross emissions for its chosen inventory boundary, separate from and independent of any GHG trades it might engage in.

The following should also be reported:

- The year that was chosen as the base year, and an emissions profile over time that is consistent with and clarifies the chosen policy for making base year emissions recalculations.

- Appropriate context for any significant emissions changes that trigger base year emissions recalculation (acquisitions/divestitures, outsourcing/insourcing, changes in reporting boundaries or calculation methodologies, etc.).
- Methodologies used to calculate or measure emissions, providing a reference or link to any calculation tools used.
- Any specific exclusions of sources, facilities, and/ or operations.

2.3.3 SASB Standards

SASB Standards identify the subset of environmental, social, and governance issues most relevant to financial performance in 77 industries (SASB, 2021). The Standards are designed to help companies disclose financial-material sustainability information for investors. In 2021, 48% of the reports reviewed by WBCSD referenced the SASB standards, compared to just 9% in 2018 (World Business Council for Sustainable Development (WBCSD) & Radley Yeldar, 2021).

The following SASB Standards have been selected:

- The entity shall disclose its fatality rate for work-related fatalities (RR-WT-320a.1.2).
- The entity shall disclose the total amount of energy it consumed as an aggregate figure, in gigajoules (GJ) (RR-ST-130a.1.1).
- The entity shall disclose the percentage of energy it consumed that was supplied from grid electricity (RR-ST-130a.1.2).
- The entity shall disclose the percentage of energy it consumed that is renewable energy (RR-ST-130a.1.3).
- The entity shall disclose its emissions of air pollutants, in metric tons per pollutant, that are released into the atmosphere (RR-BI-120a.1.1).
- The entity shall disclose the total number of instances it found itself in non-compliance, including violations of a technology-based standard and exceedances of a quality-based standard. (RR-BI-120a.2.1).
- The entity shall describe its strategic approach to managing its risks associated with the use of critical materials in its products, including physical limits on availability and access, changes in price, and regulatory

and reputational risks. A critical material is defined as a material that is both essential in use and subject to the risk of supply restriction (RR-FC-440a.1.1).

- The entity shall identify the critical materials that present a significant risk to its operations, the type of risk(s) they represent, and the strategies the entity uses to mitigate the risk(s) (RR-FC-440a.1.2).

Standards' guidelines:

Some relevant guidelines include the following:

- The entity shall consistently apply conversion factors for all data reported under specific disclosures.
- All disclosure shall be sufficient such that it is specific to the risks the entity faces but disclosure itself would not compromise the entity's ability to maintain confidential information (RR-FC-440a.1.3).

2.3.4 CSA

The S&P Global Corporate Sustainability Assessment (CSA) is an annual evaluation of companies' sustainability practices. It covers over 10,000 companies from around the world. The CSA focuses on sustainability criteria that are both industry-specific and financially material.

The following CSA Standards have been selected (CSA, 2021):

- Emerging Risks

Please indicate two important long-term (3-5 years+) emerging risks that your company identifies as having the most significant impact on the business in the future, and indicate any mitigating actions that your company has taken in light of these risks. For each risk, please provide supporting evidence from your public reporting for the description of the risk, the business impact and any mitigating actions.

- Risk Culture

What strategies does your company pursue in order to promote and enhance an effective risk culture throughout the organization?

- Supplier Code of Conduct:

Does your company have a Supplier Code of Conduct and is it publicly available? Which of the following issues are covered by the Code?

  - Environmental standards for the suppliers' processes, products or services
  - Child labor
  - Fundamental human rights (e.g., labor, freedom of association, ILO conventions) working hours, lay-off practices, remuneration)
  - Occupational health and safety
  - Business ethics (e.g., corruption, anti-competitive practices)
  - Our suppliers should have a sustainable procurement policy in place for their own suppliers

- Supply Chain Risk Exposure

Does your company have a formalized process in place to identify potential sustainability risks in the supply chain?

- Supplier Risk Management Measures

Please indicate which measures your company has taken in order to manage sustainability risks amongst your critical suppliers (tier 1 and non-tier 1) and your high sustainability risk suppliers.

- ESG Integration in SCM Strategy

Please indicate the main priorities of your company's general supply chain management strategy as well as the environmental, social and governance (ESG) objectives that have been identified in your company. Further, please indicate how ESG factors are integrated in your supplier selection decisions.

- Environmental Reporting-Coverage

Does your company publicly report on quantitative environmental indicators? If yes, please indicate where the coverage of these indicators is clearly indicated in your public reporting.

- Environmental Reporting-Assurance

Please indicate what type of external assurance your company has received in relation to your company's environmental reporting.

- The assurance statement is an "External Audit" or "External Assurance" produced by assurance specialists (e.g., accountants, certification bodies, specialist consultancies)
- The assurance statement contains a "declaration of independence" which specifies that the assurance provider has no conflict of interest in relation to providing the assurance of environmental data for the company which has been assured
- The assurance statement is based on a recognized international or national standard (e.g., AA1000AS, ISAE 3000)
- The scope of the assurance statement is clearly indicated in the assurance statement. If the assurance statement only covers some KPIs (but not all) it is clearly indicated which data/KPIs disclosed in the report have been assured (e.g., each KPI assured is marked with an "assurance" symbol/flag)
- The assurance statement contains a conclusion, i.e., either "reasonable assurance" or "limited assurance"
- We do not have any external assurance on our environmental reporting
- Not applicable
- Not known
- Coverage of Environmental Management Policy

Is your company's environmental management policy publicly available? If so, please indicate which of the following options are covered by your policy and indicate and provide supporting evidence of where this is clearly stated in the public domain.

- Production operations and business facilities
- Products and services
- Distribution and logistics
- Management of waste
- Suppliers, service providers and contractors

- Other key business partners (e.g., non-managed operations, joint venture partners, licensees, outsourcing partners, etc.)
- Due-diligence, mergers and acquisitions
- Other, please specify

▪ EMS: Certification/ Audit/ Verification

Please indicate how your Environmental Management System (EMS) is certified / audited / verified and indicate the coverage of this verification for the selected standard.

The standards are:

- International standards (e.g., ISO 14001, JIS Q 14001, EMAS certification)
- Third party certification /audit / verification by specialized companies
- Internal certification /audit / verification by company's own specialists from headquarters
- Direct Greenhouse Gas Emissions (Scope 1)

Please provide your company's total direct greenhouse gas emissions (DGHG SCOPE 1) for the part of your company's operations for which you have a reliable and auditable data acquisition and aggregation system.

▪ Indirect Greenhouse Gas Emissions (Scope 2)

Please provide your company's indirect greenhouse gas emissions from energy purchased (purchased and consumed, i.e., without energy trading) (IGHG SCOPE 2) for the part of your company's operations for which you have a reliable and auditable data acquisition and aggregation system.

▪ Energy Consumption

Please indicate the total energy consumption in the following energy categories:

- Non-renewable fuels (nuclear fuels, coal, oil, natural gas, etc.) purchased and consumed (MWh)
- Non-renewable electricity purchased (MWh)
- Steam/heating/cooling and other energy (non-renewable) purchased (MWh)

- Total renewable energy (wind, solar, biomass, hydroelectric, geothermal, etc.) purchased or generated. (MWh)
- Total non-renewable energy (electricity and heating & cooling) sold (MWh)
- Total costs of energy consumption (Currency)

▪ Climate Risk Management

Does your organization apply the TCFD framework in the management of climate-related risks and opportunities?

▪ Climate-Related Management Incentives

Do you provide incentives for the management of climate change issues, including the attainment of targets?

▪ Climate Change Strategy

How are your organizations' processes for identifying, assessing, and managing climate-related issues integrated into your overall risk management? (e.g., integrated into multi-disciplinary company-wide risk management processes, i.e., a documented process where climate change risks and opportunities are integrated into the company's centralized enterprise risk management program covering all types/sources of risks and opportunities, a specific climate change risk management process, i.e., a documented process which considers climate change risks and opportunities separate from other business risks and opportunities.)

▪ Financial Risks of Climate Change

Have you identified any climate change risks (current or future) that have potential to generate a substantive change in your business operations, revenue or expenditures?

▪ Financial Opportunities Arising from Climate Change

Have you identified any climate change-related opportunities (current or future) that have the potential to generate a substantive positive change in your business operations, revenue, expenditure (i.e., opportunities driven by changes in regulation, physical, or other climate change-related developments)?

▪ Climate Risk Assessment-Physical Risks

Has your company assessed physical risks related to climate change?

- Climate Risk Assessment- Transition Risks

Has your company assessed transition risks related to climate change?

- Physical Climate Risk Adaptation

Based on your climate risk assessment, has your company set up a plan to adapt to the identified physical climate risks?

- Climate-Related Targets

Does your company have any corporate-level climate-related targets?

- Scope 3 GHG Emissions

Please specify the top 3 most relevant sources of scope 3 emissions that are relevant to your organization and account for your scope 3 emissions in financial year 2020.

2.3.5 ATHEX ESG index

The Athens Stock Exchange introduced in 2019 a set of guidelines that help companies identify the ESG-related issues they should consider disclosing and managing, based on their impact on long-term performance, as well as metrics companies should use to disclose this information and communicate it to their stakeholders (ATHEX, 2019).

Based on these guidelines, the ATHEX ESG index has emerged, and the companies started reporting on their ESG indices during 2021. A total of 49 publicly listed companies have begun reporting, and the number continues to rise.

The indices are based on practices outlined in international sustainability guidelines such as SASB’s industry-specific standards and reporting frameworks, GRI, CDP, and the Greek Sustainability Code, as well as current ESG disclosure practices in the Greek market (ATHEX, 2019).

The following ATHEX ESG reporting indices have been selected:

- C-E1: Scope 1 emissions

Indicator C-E1 requires the reporting organization to disclose its gross direct Scope 1 GHG emissions, in tons of CO_2 equivalent.

All GHG emissions covered by the Kyoto Protocol shall be included in Scope 1 emissions. The organization should identify emissions deriving from, but not limited to the following sources:

- Generation of electricity, heating, cooling, and steam
- Physical or chemical processing
- Transportation of materials, products, waste, employees, and passengers
- Fugitive emissions

Direct CO_2 emissions from the combustion of biomass shall not be included.

- C-E2: Scope 2 emissions

Indicator C-E2 requires the reporting organization to disclose its gross indirect Scope 2 GHG emissions, in tons of CO_2 equivalent.

All GHG emissions covered by the Kyoto Protocol shall be included in Scope 2 emissions. The organization should report the emissions from the generation of purchased electricity that is consumed in its owned or controlled equipment or operations as Scope 2.

- C-E3: Energy consumption within the organization

Indicator C-E3 requires the reporting organization to disclose the:

- Total amount of energy consumed within the organization, in MWh
- Percentage of electricity consumed (%)
- Percentage of energy consumed from renewable sources (%)

The formula for the total energy consumption within an organization is as follows:

Total energy consumption within the organization = (Non–renewable fuel consumed) + (Renewable fuel consumed) + (electricity, heating, cooling and steam purchased for consumption) + (self–generated electricity, heating, cooling and steam, which are not consumed) - (electricity, heating, cooling and steam sold)

- C-G1: Sustainability oversight

Indicator C-G1 requires the reporting organization to disclose whether the organization's Board of Directors (BoD) provides sustainability oversight at the board committee level or whether Sustainability is discussed with Management during BoD meetings or not.

- A-E1: Scope 3 emissions

Indicator A-E1 requires the reporting organization to disclose its gross indirect Scope 3 GHG emissions, in tons of CO2 equivalent. All GHG emissions covered by the Kyoto Protocol shall be included in Scope 3 emissions.

- A-E2: Climate change risks and opportunities

Indicator A-E2 requires the reporting organization to discuss any climate change risks and opportunities that it pertains to. The organization should disclose the climate-related risks that TCFD recognizes. TCFD acknowledges two major climate risk categories, transition and physical risks.

- A-S5: Sustainable product revenue

Indicator A-S5 requires the reporting organization to disclose its revenue generated from products and services that have environmental and / or social benefits, in percentage (%). The organization should elaborate on the products and services it has identified as those with environmental and / or social benefits. These could include activities that substantially contribute to circular economy, achievement of the SDGs, mitigation of or adaptation to climate change etc. In defining sustainable products and services, organizations may refer to green and sustainability taxonomies and definitions outlined by institutions, international initiatives and industries, such as the EU classification system for environmentally sustainable economic activities (EU Taxonomy) and the Climate Bonds Taxonomy developed by the Climate Bonds Initiative.

- SS-E1: Emission strategy

Indicator SS-E1 requires the reporting organization to disclose any long and short-term strategies in relation to the management, mitigation and performance targets of its emissions.

- SS-E2: Air pollutant emissions

Indicator SS-E2 requires the reporting organization to disclose the total amount of NOx, SOx, volatile organic compounds and particulate matter 10 micrometers or less in diameter emitted, in kilograms.

2.3.6 Refenitiv ESG

Refinitiv is a prominent financial markets data and infrastructure provider that is a member of the LSEG (London Stock Exchange Group).

Refinitiv reports, among others, on an ESG index, covering more than 450 different ESG metrics. Refinitiv's ESG scores are based on publicly available data and are designed to evaluate a company's relative ESG performance, commitment, and effectiveness across ten primary categories (resource use, emissions, innovation, workforce, human rights, community, product responsibility, management, shareholders and CSR strategy) (Refenitiv, 2020).

The following Refenitiv ESG metrics have been selected:

- Does the company report on its environmental expenditures or does the Company report to make proactive environmental investments to reduce future risks or increase future opportunities?
- Does the company have a policy to improve emission reduction?
- Has the company set targets or objectives to be achieved on emission reduction?
- Total Carbon dioxide (CO_2) and CO_2 equivalents emission in tonnes.
- Does the company report on initiatives to reduce, reuse, recycle, substitute, or phase out SOx (sulfur oxides) or NOx (nitrogen oxides) emissions?
- Total amount of NOx emissions emitted in tonnes.
- Total amount of SOx emissions emitted in tonnes.
- Does the company report on initiatives to reduce, substitute, or phase out volatile organic compounds (VOC) or particulate matter less than ten microns in diameter (PM10)?
- Does the company report on initiatives to reduce, substitute, or phase out volatile organic compounds (VOC)?
- Does the company report on initiatives to reduce, substitute, or phase out particulate matter less than ten microns in diameter (PM10)?

- Total amount of volatile organic compounds (VOC) emissions in tonnes.
- Does the company report on partnerships or initiatives with specialized NGOs, industry organizations, governmental or supra-governmental organizations, which are focused on improving environmental issues?
- Direct and accidental oil and other hydrocarbon spills in thousands of barrels (kbls).
- Total amount of environmental expenditures.
- Does the company report on making proactive environmental investments or expenditures to reduce future risks or increase future opportunities?
- Total CO_2 and CO_2 Scope Three equivalent emission in tonnes.
- The equivalent of the CO_2 offsets, credits and allowances in tonnes purchased and/or produced by the company during the fiscal year.
- Environmental fines as reported by the company.
- The estimated total CO_2 and CO_2 equivalents emission in tonnes.
- Total amount of environmental R&D costs (without clean up and remediation costs).
- Does the company claim to evaluate projects on the basis of environmental or biodiversity risks as well?
- Does the company develop products or technologies for use in the clean, renewable energy (such as wind, solar, hydro and geothermal and biomass power)?
- Does the company have an environmental management team?
- Does the company train its employees on environmental issues?
- Does the company have a policy to improve its energy efficiency?
- Has the company set targets or objectives to be achieved on energy efficiency?
- Total direct and indirect energy consumption in gigajoules.
- Electricity purchased in gigajoules.
- Electricity produced in gigajoules.
- Total primary renewable energy purchased in gigajoules.
- Total energy produced from primary renewable energy sources in gigajoules.
- Does the company make use of renewable energy?

- Does the company use environmental criteria (ISO 14000, energy consumption, etc.) in the selection process of its suppliers or sourcing partners?
- Number of controversies related to the environmental impact of the company's operations on natural resources or local communities.
- Percentage of emission reduction target set by the company.
- The year by which the emission reduction target is set.
- Percentage of revenue from environmental products and services offered by the company.
- Does the financial company have a public commitment to divest from fossil fuel?
- Total primary renewable energy purchased and produced in gigajoules.
- Percentage of Grid or Transmission loss as reported by the company.
- Does the company have a CSR committee or team?
- Has the company signed the UN Global Compact?
- Does the company publish a separate CSR/H&S/Sustainability report or publish a section in its annual report on CSR/H&S/Sustainability?
- Is the Company's CSR report published in accordance with the GRI guidelines?
- Does the company have an external auditor of its CSR/H&S/Sustainability report?
- Does the company support the UN Sustainable Development Goal 7 (SDG 7) Affordable and Clean Energy?
- Does the company support the UN Sustainable Development Goal 11 (SDG 11) Sustainable Cities and Communities?
- Does the company support the UN Sustainable Development Goal 12 (SDG 12) Responsible Consumption and Production?
- Does the company support the UN Sustainable Development Goal 13 (SDG 13) Climate Action?
- Does the company support the UN Sustainable Development Goal 14 (SDG 14) Life Below Water?
- Does the company support the UN Sustainable Development Goal 15 (SDG 15) Life on Land?

- Number of controversies published in the media linked to responsible R&D.
- Does the company train its executives or key employees on health & safety?
- Does the company have a policy to improve employee health & safety?
- Does the company have health and safety management systems in place like the OHSAS 18001 (Occupational Health & Safety Management System)?
- Total number of injuries and fatalities including no-lost-time injuries relative to one million hours worked.
- Number of controversies published in the media linked to workforce health and safety.

2.4 DSS Lab’s methodology

The due diligence checklist created in this thesis will complement the ESG toolkit developed by the Decision Support Systems (DSS) Laboratory of the National Technical University of Athens. The toolkit calculates ESG scores and enables Banks / Financial Institutions (FIs) to identify and assess potential ESG risks and opportunities in their investments.

The toolkit functions as follows. The user enters the company’s name, the name of the project, the investment amount, and the sector in which the company belongs. The toolkit automatically calculates the ESG score, as high, medium, or low, for each ESG pillar (Environmental, Social, and Governance) and provides a due diligence checklist for each pillar based on the scoring. The pillar in the due diligence checklist is divided into sub-categories, as presented in Table 1.

Based on the checklists, the user is asked to score every pillar’s sub-category with a score ranging from 0 to 3, where 0 is low and 3 is high, to assess and rate the company. The filled scores will be used to automatically calculate the company’s final, numerical ESG score. The user also identifies risks and opportunities for each sub-category.

Apart from the checklist per each ESG pillar, an additional rating checklist has been created for critical sectors. The user should also consider the additional checklist while scoring for these sectors. One of the nine critical sectors examined is the Energy Sector.

ENVIRONMENT	
1.1	**Register of Regulations**
1.2	**Pollution Abatement and Testing**
1.3	**Resource Efficiency**
1.4	**Greenhouse Gases emissions reduction**
1.5	**Environment Policy and organization structure**
1.6	**Certification of Environment Management System**
1.7	**Disclosure and Reporting**
1.8	**Environment Management Plan**

SOCIAL	
2.1	**Social Policy**
2.2	**Grievance Redressal Mechanism**
2.3	**Monitoring/ Audits**
2.4	**Minimize impacts and provide fair compensation and livelihood restoration**
2.5	**Emergency Plans**
2.6	**Health and Safety Policy and training**

GOVERNANCE	
3.1	**Promoting a fair and transparent way of doing business**
3.2	**Ensure good governance practices at the Company**
3.3	**Ensure adequate internal checks for managing risks**

Table 1 Environment, Social and Governance due diligence checklist sub-categories.

2.5 Checklist for the Energy Sector

Based on the standards examined in this Chapter and taking into account the sustainability-related frameworks and policies, as examined in Chapter 1, the checklist presented in Table 2 for companies active in the Energy Sector has been created. The checklist, aiming to be easily integrated into SDD Laboratory's toolkit, follows the toolkit structure as presented above. It should be noted that the criteria covered in the Laboratory's general Environmental, Social, and Governance due diligence checklists are not included in the checklist.

ENVIRONMENT
1.1 Register of Regulations
Has the company received fines for non-compliance with energy regulations?
Has the company had controversies related to the environmental impact of its operations on natural resources?
1.2 Pollution abatement and testing
Are the direct and accidental oil and other hydrocarbon spills acceptable compared to the industry average? Please provide documentation for the company's and the industry's spills.
Does the company report on initiatives to reduce, substitute, or phase out volatile organic compounds (VOC) or particulate matter less than ten microns in diameter (PM10)? Please provide supporting evidence from the Company's public reporting.
1.3 Resource efficiency
Has the company set targets/objectives/policies for energy efficiency? If yes, please provide supporting evidence from the company's public reporting.
Has reduction in energy consumption been reported as a result of conservation and efficiency initiatives? If yes, is the amount acceptable compared with that of other same-sized companies in the industry? Please provide supporting evidence from the company's public reporting.
Does the company have a public commitment to divest from fossil fuel? If yes, please provide supporting evidence from the company's public reporting.
Does the company develop products or technologies for clean, renewable energy (such as wind, solar, hydro and geothermal, and biomass power)? If yes, please provide supporting evidence from the company's public reporting.

Is the amount of renewable energy produced as a percentage of the total energy produced acceptable compared with that of same-sized companies in the industry? Please provide documentation for the company's and the industry's energy production.
Is the amount of renewable energy purchased as a percentage of the total energy produced acceptable compared with that of same-sized companies in the industry? Please provide documentation for the company's and the industry's energy purchases.
Is the amount of renewable energy sold as a percentage of the total energy produced acceptable compared with that of same-sized companies in the industry? Please provide documentation for the company's and the industry's energy sales.
Is the percentage of grid or transmission loss acceptable compared with that of same-sized companies in the industry? Please provide documentation for the company's and the industry's energy losses.
Is the energy consumption outside the company, resulting from its activity (e.g., use of sold products, waste generated in operations, etc.) acceptable, compared with that of other companies in the industry? Please provide documentation for the company's and the industry's outside consumption.
1.4 Greenhouse gases emissions reduction
Has the company set targets/ objectives/policies for GHG management/reduction? If yes, please indicate the reduction percentage and the target year.
Does the company report on greenhouse gas emissions? If yes, please specify any international methodology/standard used.
Is the amount of total scope 1 emissions acceptable compared with that of same-sized companies in the industry? Please provide documentation for the company's and the industry's scope 1 emissions.

Is the amount of total scope 2 emissions acceptable compared with that of same-sized companies in the industry? Please provide documentation for the company's and the industry's scope 2 emissions.
Is the amount of total scope 3 emissions acceptable compared with that of same-sized companies in the industry? Please provide documentation for the company's and the industry's scope 3 emissions.
Are the emissions of the GHGs covered by the Kyoto Protocol (CO2, CH4, N2O, HFCs, PFCs, SF6) and not covered (e.g., CFCs, NOx,) acceptable based on the Country's regulations? Please provide supporting evidence from the company's public reporting.
1.7 Disclosure and reporting
Does the company publish a separate CSR/Sustainability report? If yes, please provide the link to the report.
SOCIAL
2.6 Health and safety policy and training
Does the company train its employees on environmental and energy issues?
GOVERNANCE
3.1 Promote a fair and transparent way of doing business
Is the CSR/Sustainability report, if in place, reviewed by external auditors? If yes, please provide supporting evidence from the company's public reporting.
Is the CSR/Sustainability report, if in place, published following the GRI guidelines? If yes, please provide supporting evidence from the company's public reporting.
3.3 Ensure adequate internal checks for managing risks

Has the company identified important long-term emerging energy-related risks? If yes, please provide supporting evidence from the company's public reporting.
Has the company made any environmental investments – expenditures to reduce future energy-related risks or increase future opportunities? If yes, please provide supporting evidence from the company's public reporting.
Does the organization apply the TCFD or any other established framework to manage energy-related risks and opportunities? If yes, please provide supporting evidence from the company's public reporting.

Table 2 Due diligence checklist for the Energy Sector.

3. Regression analysis

The ESG score provides an easy-to-use metric that quantifies a firm's environmental and social policies while also providing valuable information regarding its management and governance practices, which is often inaccessible for the majority of the investors.

The rising popularity of the ESG metric is connected with the increased global concern over environmental, social, and governance issues. Modern-day investors have become more aware of the environmental and social implications of a firms' malpractices. Understanding their influence on firms, they seek to finance more ESG aware companies. Also, since buyers are becoming more interested in companies that follow ethical practices, investing in companies with high ESG scores is a good decision from a financial perspective. It is, thus, evident that the ESG score can shape the opinion of the shareholders and the stock market over a publicly traded firm, affecting, therefore, its stock price.

The regression analysis presented in this Chapter examines and evaluates the impact of ESG ratings on energy companies. More specifically, the study investigates the effect ESG can have on the firm's market value and risk (as expressed by the price volatility).

3.1 Multiple linear regression theory

This Section focuses on briefly presenting the basic theory behind the classic linear regression model. The structure of the regression model is presented along with the necessary assumptions. Crucial tests to assess the model's unbiasedness, consistency, and efficiency are also examined.

3.1.1 Model structure

A multiple linear regression model that relates a y variable to x variables and can be written as:

$$y_i = \beta_0 + \beta_1 \cdot x_{1,i} + \beta_2 \cdot x_{2,i} + \cdots + \beta_p \cdot x_{p,i} + \varepsilon_i$$

where:

- y_i : the i-th observation of the dependent variable (response variable).
- $x_{j,i}$: the i-th observation of the j-th independent variable (regressor).
- β_0 : the regression intercept term.
- β_j : the slope coefficient (regression parameter) of the j-th independent variable.
- ε_i : the error term (residual) of the i-th observation.
- p: the number of independent variables.

Each β coefficient represents the change in the mean response, $E(y)$, per unit increase in the associated predictor variable when all the other predictors are held constant. The intercept term, β_0, represents the mean response, $E(y)$, when all the predictors are zero.

Assumptions

The model relies on the following assumptions:

- The relationship between the dependent variable and each independent variable is linear.
- Errors corresponding to different observations are independent.
- The error terms follow a normal distribution of zero mean and constant variance.

$$\varepsilon \sim N(0, \sigma^2)$$

- The error terms are not correlated with the independent variables.
- There is no correlation among the independent variables (no multicollinearity).

3.1.2 Coefficient calculation

The regression model aims to determine the relationship between the dependent and the independent variables of the sample in an attempt to reflect the actual relationship among the variables of the population. The current study estimates the regression equation through the Ordinary Least Squares (OLS) method, as presented below. The OLS regression coefficients can be easily calculated by employing matrix algebra.

The multiple linear regression model with p regressors and n observations:

$$y_i = \beta_0 + \beta_1 \cdot x_{1,i} + \beta_2 \cdot x_{2,i} + \cdots + \beta_p \cdot x_{p,i} + \varepsilon_i$$

can be written in matrix form as:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_p \end{bmatrix} = \begin{bmatrix} \beta_0 + \beta_1 \cdot x_{1,1} + \beta_2 \cdot x_{2,1} + \cdots + \beta_p \cdot x_{p,1} \\ \beta_0 + \beta_1 \cdot x_{1,2} + \beta_2 \cdot x_{2,2} + \cdots + \beta_p \cdot x_{p,2} \\ \vdots \\ \beta_0 + \beta_1 \cdot x_{1,n} + \beta_2 \cdot x_{2,n} + \cdots + \beta_p \cdot x_{p,n} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} \Rightarrow$$

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_p \end{bmatrix} = \begin{bmatrix} 1 & x_{1,1} & x_{2,1} & \cdots x_{p,1} \\ 1 & x_{1,2} & x_{2,2} & \cdots x_{p,2} \\ & & \vdots & \\ 1 & x_{1,n} & x_{2,n} & \cdots x_{p,n} \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_p \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} \Rightarrow Y = X \cdot \beta + \varepsilon$$

Therefore, the residuals are $\varepsilon = Y - X \cdot \beta$

The OLS calculation aims at minimizing the residual sum of squares,

$$\sum \varepsilon_i^2 = [\varepsilon_1\ \varepsilon_2\ \cdots \varepsilon_n] \cdot \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} = \varepsilon' \cdot \varepsilon = (Y - X \cdot \beta)' \cdot (Y - X \cdot \beta)$$

The first order condition for minimizing the above equation sets the partial derivative (with respect to β) equal to zero, thus the coefficients can be calculated as:

$$\frac{\partial[(Y - X \cdot \beta)' \cdot (Y - X \cdot \beta)]}{\partial \beta} = 0 \Rightarrow -2 \cdot X' \cdot (Y - X \cdot \beta) = 0 \Rightarrow X' \cdot Y = X' \cdot X \cdot \beta \Rightarrow$$

$$\beta = (X' \cdot X)^{-1} \cdot X' \cdot Y$$

Best Linear Unbiased Estimators (BLUE)

The OLS method relies on the following assumptions:

- Correct model specification, i.e., linearity of the equation.
- Exogeneity of the regressors.
- Non-randomness of the explanatory variables.
- No multicollinearity among the regressors.
- Homoscedasticity of the error terms (constant variance).
- No autocorrelation in the residuals (error terms independent of each other).
- Normality of error terms.

According to the Gauss-Markov theorem, the OLS estimators that satisfy the above assumptions are the most efficient estimators among all the linear unbiased estimators. Therefore, the OLS estimators are BLUE and satisfy the three desired properties of unbiasedness, efficiency, and consistency.

- Unbiasedness: The expected value of the unbiased estimator $\hat{y}$ is equal to the population parameter y.

$$E(\hat{y}) = y$$

- Efficiency: It is expressed by the estimator's variance (standard error). The smaller the variance, the greater the efficiency.
- Consistency: An estimator is consistent if its variance reduces as the sample size increases.

$$Var(\hat{y}) \rightarrow 0 \text{ as } n \rightarrow \infty$$

3.1.3 Correlation

The correlation among the examined parameters, both the dependent and the independent, is calculated by the Pearson correlation coefficients. Given any two parameters x and y, the Pearson correlation coefficient (ρ) of the pair (x,y) is calculated by the following formula:

$$\rho_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \cdot \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

where:

- x_i, y_i: the observations of the x and y variables.
- $\bar{x}, \bar{y}$: the mean values of the x and y variables.
- n: total number of observations.

3.1.4 Regression metrics

Coefficient of determination

The coefficient of determination, commonly known as R^2, is a significant characteristic of regression analysis as it expresses the level of fitness of the model. More specifically, it determines how much of the variation in the response can be explained by the independent variables. R^2 can be calculated by the following formula:

$$R^2 = 1 - \frac{SS_{RES}}{SS_{TOT}}$$

where:

- $SS_{RES} = \sum(y_i - \hat{y}_i)^2$: the residual sum of squares ($\hat{y}_i$ is the fitted value predicted by the regression model).
- $SS_{TOT} = \sum(y_i - \bar{y})^2$: the total sum of squares of y ($\bar{y}$ is the mean value of y).

R^2 receives values in the [0, 1] interval:

- $R^2 = 0$: The model always predicts $\bar{y}$. The outcome cannot be predicted by any of the independent variables.
- $R^2 = 1$: The model always predicts the observed y_i value and has no residuals. The outcome can be predicted without error from the independent variables.

The R^2 increases as more predictors are added to the model. It should be noted, however, that adding predictors to a model can lead to worse predictions, despite the increase of the coefficient of determination. Adding too many variables to a model makes it overly customized to fit the peculiarities and the random noise of the sample rather than reflecting the entire population. This phenomenon is known as overfitting and is a common problem in regression models.

The spurious increase of the coefficient of determination that occurs by adding extra predictors to the model can be accounted for by the adjusted R^2, which considers the number of independent variables (p) and the number of observations (n) in the calculation.

$$R^2_{ADJ} = 1 - \frac{SS_{RES}}{SS_{TOT}} \cdot \frac{n-1}{n-p-1} = 1 - (1 - R^2) \cdot \frac{n-1}{n-p-1}$$

Standard deviation

The regression analysis includes the calculation of the standard deviation (S) of the distance between the data values (y) and the fitted values ($\hat{y}$). S is measured in the units of the response.

$$S = \sqrt{\frac{\sum_1^n (w_i - \overline{w})^2}{n-1}},$$

where $w = y - \hat{y}$ and n is the number of observations of the sample.

Standard error of a coefficient

The standard error of a coefficient (SE) is calculated for each predictor variable x according to the following formula:

$$SE = \frac{S}{\sqrt{\sum_1^n (x_i - \overline{x})^2}},$$

where S is the standard error of the model.

The standard error of the coefficient is always positive, and it measures the precision of the model's estimation of the coefficients. The smaller the standard error, the more precise the estimate.

t-statistic

The t-statistic is used to test whether a coefficient is significantly different from zero. In regression models, the t-stat. is used, for each variable, including the constant, to measure the ratio of the coefficient (β) to the standard error (SE). It is calculated by the following formula:

$$\text{t-stat.} = \frac{\beta}{SE}$$

F-statistic

The F-stat. is used to assess whether all coefficients are jointly significant (at least one is different from zero) and is calculated as:

$$\text{F-stat.} = \frac{SS_{REG}/DF_{REG}}{SS_{RES}/DF_{RES}} = \frac{R^2}{1-R^2} \cdot \frac{n-p-1}{p}$$

where:

- $SS_{REG} = \sum(\hat{y}_i - \bar{y})^2$: the regression sum of squares.
- $DF_{REG} = p$: the degrees of freedom of the regression model.
- $SS_{RES} = \sum(y_i - \hat{y}_i)^2$: the residual sum of squares.
- $DF_{RES} = n - 1 - p$: the degrees of freedom of the residuals (error).

The F-stat. can also be calculated for each independent variable, similarly to t-stat., as:

$$\text{F-stat.} = \frac{SS_{ADJ\ REG}}{SS_{RES}/DF_{RES}} = \frac{SS_{ADJ\ REG}}{S^2}$$

where:

- $SS_{ADJ\ REG}$: the adjusted regression sum of squares of the independent variable.
- $SS_{RES} = \sum(y_i - f_i)^2$: the residual sum of squares.
- $DF_{RES} = n - 1 - p$: the degrees of freedom of the residuals (error).

The adjusted regression sum of squares of each independent variable occurs as follows:

1. The respective variable is removed from the model, and a new model is formed with the remaining variables as predictors.
2. The regression sum of squares is calculated for the new model.
3. The difference between the regression sums of squares of the two models is the adjusted regression sum of squares of the removed predictor.

It is evident that the $SS_{ADJ\ REG}$ quantifies the amount of variation in the response explained by the model's respective term.

3.1.5 Coefficient diagnostics

Multicollinearity

An ideal regression model would consist of independent variables that are highly, or even perfectly, correlated with the dependent variable but utterly uncorrelated with each other. In most cases, however, the predictors are correlated at some level, either positively or negatively. High correlation among the independent variables may lead to multicollinearity, which occurs when an independent variable can be linearly predicted from other independent variables with a substantial degree of accuracy. The model's coefficients behave erratically in response to small changes in the data under the presence of multicollinearity. As a result, while preserving its reliability and predicting strength, the regression model may provide inaccurate results about the predictors.

The severity of multicollinearity is quantified by the Variance Inflation Factors (VIFs). The numerical value of VIF is the percentage to which the variance of a coefficient is inflated due to multicollinearity. For example, a VIF of 1.4 suggests that the variance of the coefficient is 40% greater than what it should be without multicollinearity.

A Variance Inflation Factor is calculated for each independent variable of the model according to the following procedure:

1. Assume the following regression model:

$$y = \beta_0 + \beta_1 \cdot x_1 + \beta_2 \cdot x_2 + \cdots + \beta_p \cdot x_p + \varepsilon$$

2. For each independent variable x_j, a regression model is calculated with x_j as the response and the rest of the variables as the predictors. For example, for the x_1 variable the following model is produced:

$$x_1 = \alpha_0 + \alpha_2 \cdot x_2 + \alpha_3 \cdot x_3 + \cdots \alpha_p \cdot x_p$$

3. The coefficient of determination R_j^2 is calculated for the above model. The VIF of the x_j variable is given by the following formula:

$$VIF_j = \frac{1}{1 - R_j^2}$$

A high value of VIF corresponds to a high R_j^2, which suggests that the examined independent variable can be accurately predicted by the remaining independent variables. Therefore, high values of VIF act as indicators of multicollinearity. On the other hand, a R_j^2 equal to zero suggests that the respective predictor cannot be predicted by the rest predictors, leading to a minimum VIF value of 1. The VIF's threshold value for the presence of multicollinearity is a subject of debate. As a rule of thumb, VIF's threshold is set at 10, but some more conservative approaches set it to 5 or even 2.5.

3.1.6 Residual diagnostics

Normality

As it was previously mentioned, the error terms of a regression model are assumed to follow a normal distribution of zero mean and constant variance σ^2. Before explaining the method that is followed to test the normality of the residuals, it is vital to define the skewness and kurtosis statistics, as they hold a crucial role in assessing the normality of a distribution.

The skewness and kurtosis of a distribution are determined by the 3rd and 4th moment of a variable X, around its mean μ_X. The moments are calculated as:

$$3^{rd} \text{ moment: } E[(x - \mu_X)^3]$$

$$4^{th} \text{ moment: } E[(x - \mu_X)^4]$$

Respectively, the skewness (a^3) and kurtosis (a^4) coefficients are defined as:

$$\alpha^3 = E[\left(\frac{x - \mu_X}{\sigma_X}\right)^3]$$

$$\alpha^4 = E\left[\left(\frac{x - \mu_X}{\sigma_X}\right)^4\right] - 3$$

The skewness and kurtosis are useful in assessing the shape of the distribution.

Skewness shows the degree of asymmetry in the distribution, as shown in Figure 9:

- If $\alpha^3 < 0$, the distribution has negative skewness, and the left tail of its curve is longer-flatter.

- If $\alpha^3 = 0$, the distribution is symmetric around the mean and has no kurtosis.
- If $\alpha^3 > 0$, the distribution has positive skewness, and the right tail of its curve is longer-flatter.

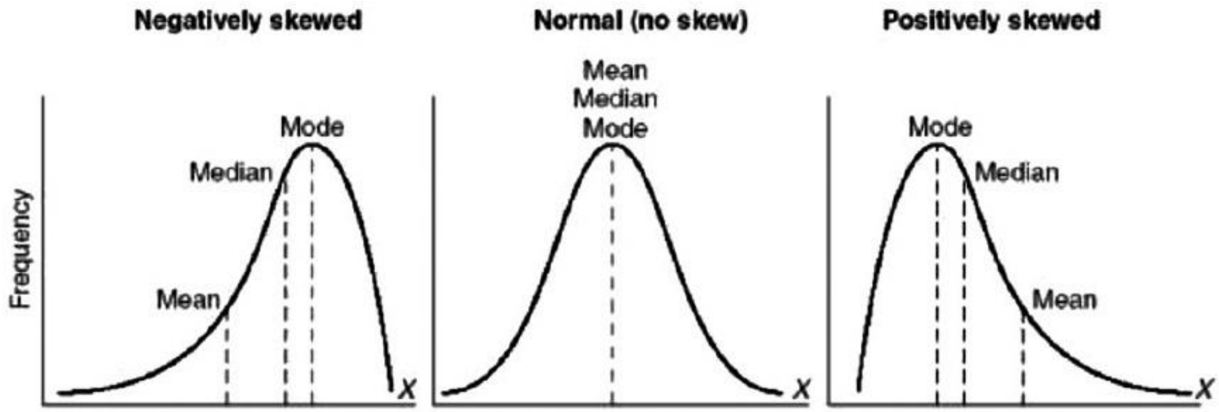


Figure 9 Distribution of negative, zero and positive skewness.

Kurtosis depicts the peakedness or flatness of the distribution, as shown in Figure 10:

- If $\alpha^4 < 3$ the distribution is platykurtic.
- If $\alpha^4 = 3$ the distribution has no kurtosis (mesokurtic).
- If $\alpha^4 > 3$ the distribution is leptokurtic.

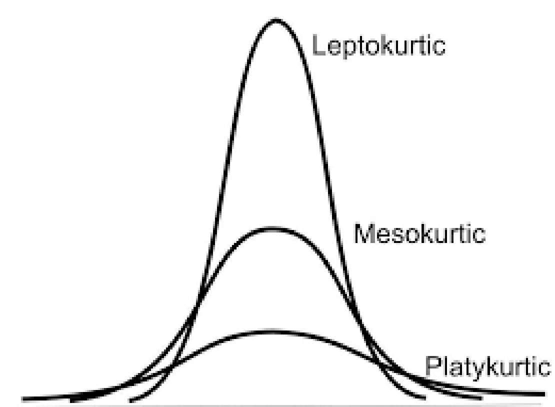


Figure 10 Platykurtic, mesokurtic, and leptokurtic distribution.

The normal distribution has neither skewness nor kurtosis, therefore $\alpha^3 = 0$ and $\alpha^4 = 3$.

The Jarque-Bera test (Bera & Jarque, 1981), is employed to test the normality of the residuals. The test examines the deviation of the skewness and the kurtosis of a given series compared to the normal distribution, using the Jarque-Bera statistic (JB), which is calculated as:

$$JB = \frac{n-k}{6} \cdot \left[SK^2 + \frac{1}{4} \cdot (KU-3)^2\right],$$

where SK is the skewness, KU is the kurtosis of the series, k is the number of estimated coefficients used to create the series, and n is the number of observations.

The Jarque-Bera statistic is the sum of the squares of two standard normally distributed random variables and follows a chi-square distribution with two degrees of freedom (skewness and kurtosis).

$$JB \sim \chi^2_{(2)}$$

The normality of the error terms is assessed according to the following procedure.

1. The null and alternative hypotheses are stated:
   - H_0: The error terms are normally distributed.
   - H_α: The error terms are non-normally distributed.
2. The level of significance α is specified.
3. The skewness and kurtosis coefficients of the residuals are calculated.
4. The Jarque-Bera statistic is calculated according to the provided formula.
5. The critical value of the test (χ^2_α) is determined from the statistical table of the chi-square distribution, according to the significance level α and the degrees of freedom (2) (Figure 11).

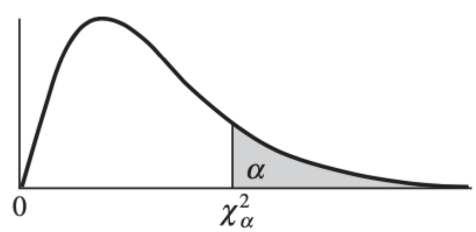


Figure 11 Distribution of the variables, critical value of the test (χ^2_α) and significance level α.

6. The JB statistic is compared with the critical value.
   - If $JB > \chi^2_\alpha$, reject the null hypothesis → the residuals are not normally distributed.
   - If $JB \leq \chi^2_\alpha$, fail to reject the null hypothesis → the residuals are normally distributed.

Heteroskedasticity

One of the main assumptions of the classic linear regression model is that the error terms follow a normal distribution of zero mean and constant variance σ^2. The assumption of constant variance is called homoskedasticity and is mathematically expressed as:

$$E(\varepsilon_i - \bar{\varepsilon})^2 = \sigma^2$$

Heteroskedasticity occurs when the variance of the error terms is not constant:

$$E(\varepsilon_i - \bar{\varepsilon})^2 = \sigma_i^2$$

The presence of heteroskedasticity does not affect the unbiasedness or the consistency of the regression estimators but impacts their efficiency. The estimates of the standard errors of the regression coefficient are downwardly biased, meaning that the SEs are smaller than what they should be. As a consequence, invalid conclusions may be drawn during hypothesis testing.

Heteroskedasticity can often be detected simply by plotting the residual's graph (Figure 12).

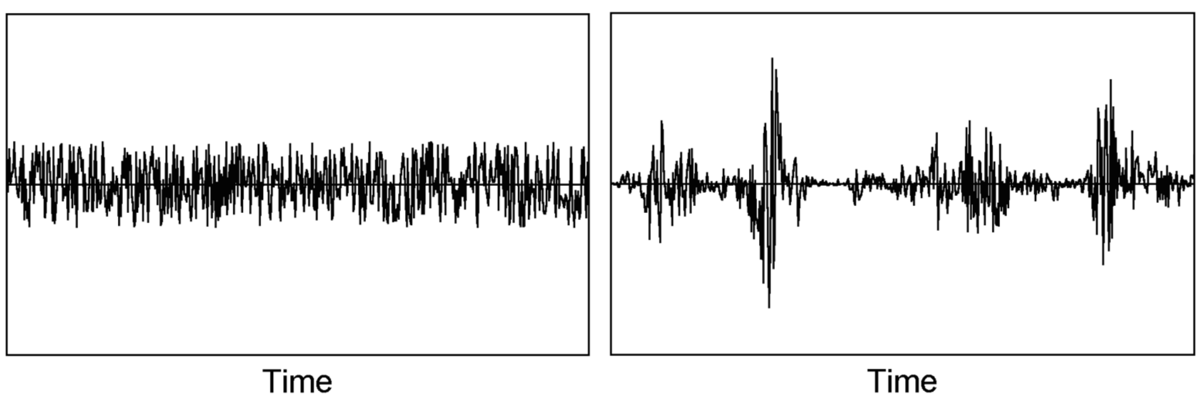


Figure 12 Homoscedasticity (left) and heteroskedasticity (right).

As observed in the left graph, the variable deviates from its mean in a constant and stable pattern, suggesting a constant standard deviation that indicates homoskedasticity. In the right graph, some regions present very high or low standard deviations, indicating a non-constant standard deviation pattern, which is a characteristic of heteroskedasticity.

Despite the practical usefulness of graphically detecting heteroskedasticity, it is necessary to implement a formal statistical test for determining the presence or absence of heteroskedasticity. For this purpose, the White test is employed (White, 1980). The procedure followed is explained by the example below.

1. Assuming the following regression model:

$$y_i = \beta_0 + \beta_1 \cdot x_{1,i} + \beta_2 \cdot x_{2,i} + \varepsilon_i$$

2. The squared residuals are regressed according to the following auxiliary regression:

$$\varepsilon_i^2 = \alpha_0 + \alpha_1 \cdot x_{1,i} + \alpha_2 \cdot x_{2,i} + \alpha_3 \cdot x_{1,i}^2 + \alpha_4 \cdot x_{2,i}^2 + \alpha_5 \cdot x_{1,i} \cdot x_{2,i} + v_i$$

   The auxiliary regression is used to assess a possible relationship between the variance of the residuals and the independent variables of the main regression.

3. The null and alternative hypotheses are stated:
   - H_0: $\alpha_0 = \alpha_1 = \cdots = \alpha_5 = 0$ (homoskedasticity).
   - H_α: At least one of the coefficients is significantly different from zero.
4. The level of significance α is specified.
5. The $n \cdot R^2$ value is calculated, where n is the number of observations of the main regression and R^2 is the coefficient of determination of the auxiliary regression. The statistic follows a chi-square distribution with k degrees of freedom, where k is the number of regressors of the auxiliary regression.

$$n \cdot R^2 \sim \chi^2_{(k)}$$

6. The critical value of the test (χ^2_α) is determined from the statistical table of the chi-square distribution, based on the significance level α and the degrees of freedom (k) (Figure 13).

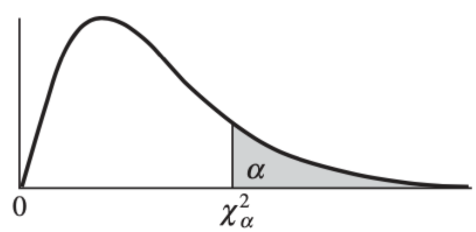


Figure 13 Distribution of the variables, critical value of the test (χ^2_α) and significance level α.

7. The $n \cdot R^2$ statistic is compared with the critical value.
   - If $n \cdot R^2 > \chi^2_\alpha$, reject the null hypothesis → heteroskedasticity in the residuals.

- If $n \cdot R^2 \leq \chi^2_\alpha$, fail to reject the null hypothesis → homoskedasticity in the residuals.

If heteroskedasticity is detected in the residuals, the White correction can be implemented as a remedial measure.

White correction

The White correction (White, 1980) uses a heteroscedasticity consistent covariance matrix estimator that provides correct estimates of the coefficient covariances in the presence of heteroscedasticity of unknown form. It is beneficial in cases that the form of heteroskedasticity, or simply the variance of the residuals, is not known.

The White covariance matrix is given by:

$$\hat{\Sigma}_W = \frac{T}{T-k} \cdot (X'X)^{-1} \cdot \left(\sum_{t=1}^{T} \varepsilon_t^2 \cdot x_t \cdot x_t'\right) \cdot (X'X)^{-1}$$

where T is the number of observations, k is the number of regressors and X is the matrix of the independent variables.

3.1.7 Forecasts

Econometric models are often used for providing forecasts for the observed dependent variables. Forecasts can be ex-post and ex-ante; in the ex-post forecasts, the values of the independent and dependent variables are observed and known with certainty, and, thus, the performance of the forecast can be evaluated; in the ex-ante forecasts, the values of the independent variables may or may not be known. The ex-post forecasts are, therefore, unconditional forecasts since all explanatory variables are known with certainty, whereas the ex-ante forecasts may be conditional if at least one of the explanatory variables is not known with certainty for the examined period. A visual representation of the models is shown in Figure 14. For the current work, forecasts are used to assess the model, thus forecasts have been made only for the ex-post period.

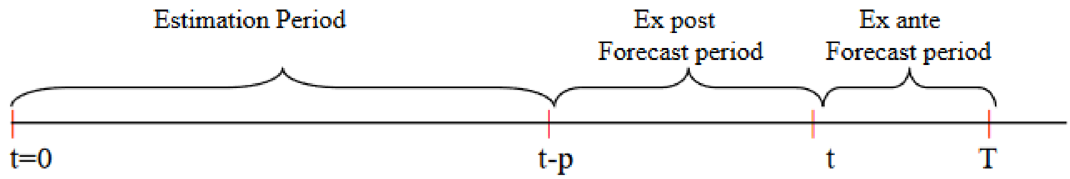


Figure 14 Ex-post and ex-ante forecasting period.

Forecasting errors can occur due to:

- The random error terms of the regression (unexplained variation).
- The estimation process of the regression parameters.
- The estimation of the independent variables (for conditional forecasts).
- The model specification (e.g., use of linear model instead of non-linear).

Assuming the following regression model,

$$y_i = \beta_0 + \beta_1 \cdot x_{1,i} + \beta_2 \cdot x_{2,i} + \cdots + \beta_p \cdot x_{p,i} + \varepsilon_i$$

an unconditional forecast for y_{i+1}, given the $x_{1,i+1}, x_{2,i+1}, \dots, x_{p,i+1}$, is:

$$\hat{y}_{i+1} = E(y_{i+1}) = \beta_0 + \beta_1 \cdot x_{1,i+1} + \beta_2 \cdot x_{2,i+1} + \cdots + \beta_p \cdot x_{p,i+1}$$

The forecasting error can be calculated as

$$\hat{e}_{i+1} = \hat{y}_{i+1} - y_{i+1}$$

and has two basic properties:

- The mean of the forecasting errors is zero (unbiasedness).
- The forecasting error variance has the minimum variance among all the possible linear-based forecasts.

The evaluation of the forecasting performance relies on assessing the degree to which the forecasted values track the actual values. Assuming a variable y, for which y^a are the actual values and y^f are the forecasted values over a forecasting sample of size M, then the following metrics are calculated for the evaluation of the forecasting performance.

Mean absolute error – Root mean absolute error

$$MAE = \frac{1}{M} \cdot \sum_{i=1}^{M} \left| y_i^a - y_i^f \right|$$

$$\mathrm{RMAE} = \sqrt{\frac{1}{M} \cdot \sum_{i=1}^{M} \left| y_i^a - y_i^f \right|}$$

Mean square error – Root mean square error

$$\mathrm{MSE} = \frac{1}{M} \cdot \sum_{i=1}^{M} \left(y_i^a - y_i^f \right)^2$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{M} \cdot \sum_{i=1}^{M} \left(y_i^a - y_i^f \right)^2}$$

In order to maximize the forecasting accuracy, the errors must be minimized.

Another interesting method for forecast evaluation is the Theil's inequality coefficient, or simply the Theil's U statistic (Theil, 1966), which is calculated as:

$$\text{Theil's U} = \frac{\sqrt{\frac{1}{M} \cdot \sum_{i=1}^{M} \left(y_i^a - y_i^f \right)^2}}{\sqrt{\frac{1}{M} \cdot \sum_{i=1}^{M} \left(y_i^f \right)^2} + \sqrt{\frac{1}{M} \cdot \sum_{i=1}^{M} (y_i^a)^2}}$$

The Theil's statistic ranges between 0 and 1:

- If the Theil's U is 0, there is a perfect fit between the actual and the forecasted values.
- If the Theil's U is 1, the forecasts are highly inaccurate.

The numerator of the Theil's U can be decomposed into three components as:

$$\sqrt{\frac{1}{M} \cdot \sum_{i=1}^{M} \left(y_i^a - y_i^f \right)^2} = \left(\bar{y}^f - \bar{y}^a \right)^2 - (\sigma_f - \sigma_a)^2 + 2 \cdot (1 - \rho) \cdot \sigma_f \cdot \sigma_a$$

where:

- $\bar{y}^f, \bar{y}^a$: the mean values of the forecasted and actual data.
- σ_f, σ_a: the standard deviations of the forecasted and actual data.
- ρ: the correlation coefficient between the forecasted and the actual data.

Therefore, three proportions of the Theil's U are defined:

Bias proportion

$$U^B = \frac{\left(\bar{y}^f - \bar{y}^a\right)^2}{\frac{1}{M} \cdot \sum_{i=1}^{M} (y_i^f - y_i^a)^2}$$

The bias proportion measures the extent to which the average forecasted and actual values deviate from each other and, therefore, indicates the degree of systematic error.

Variance proportion

$$U^S = \frac{(\sigma_f - \sigma_a)^2}{\frac{1}{M} \cdot \sum_{i=1}^{M} (y_i^f - y_i^a)^2}$$

The variance proportion quantifies the ability of the model to replicate the variability of the dependent variable for which the forecasts are given. Large values of the variance proportion suggest that the actual values fluctuated significantly higher (or lower) than the forecasted values.

Covariance proportion

$$U^C = \frac{2 \cdot (1 - \rho) \cdot \sigma_f \cdot \sigma_a}{\frac{1}{M} \cdot \sum_{i=1}^{M} (y_i^f - y_i^a)^2}$$

The covariance proportion represents the unsystematic errors that remain after the deviations from the average values have been accounted for.

The three proportions have the following property:

$$U^B + U^S + U^C = 1$$

3.2 Models

The Section aims to analyze and interpret regression models that are estimated for US energy firms. The models aim at reflecting the relationship between the ESG scores and the market value and risk of the companies. Once this relationship is defined, an ex-post forecast is made for 2020, and the forecasting efficiency is assessed.

For the study, a dataset of 122 US energy companies is formed. All firms currently trade in the New York Stock Exchange (NYSE) and have received at least one ESG rating by the end of 2020. The necessary financial data, as reported in the official financial statements and metrics, as calculated by financial analysts, are collected from the Thomson Reuters' Refinitiv Eikon platform for the 2015-2020 period. The models are constructed for the 2015-2019 period, while 2020 is used for forecasting.

Correlation

In order to identify the variables that best describe the models, a set of potential variables have been identified based on the bibliography. The variables selected are the following:

- LMV: Natural logarithm of market value
$$\mathrm{LMV} = \ln(\text{Market Cap}) = \ln\,(\#\ \text{ordinary share} \cdot \text{share price})$$
- LRISK: Natural logarithm of annual risk
$$\mathrm{LRISK} = \ln\left(\text{st. dev}(\mathrm{R_t}) \cdot \sqrt{\#\ \text{trading days}}\right)$$
- AT: Asset Turnover
  It helps to understand how effectively companies are using their assets to generate sales.
$$\mathrm{AT} = \frac{\text{Net sales}}{\text{Total assets}}$$
- CURR: Current asset ratio
  Current assets are those that can be easily converted into cash (within one year).
$$\mathrm{CURR} = \frac{\text{Current assets}}{\text{Total assets}}$$
- TANG: Tangibility ratio
  Tangible assets are the assets that have physical form, such as cash, inventory, vehicles, equipment and buildings.
$$\mathrm{TANG} = \frac{\text{Tangible assets}}{\text{Total assets}}$$
- CH: Cash Holdings
$$\mathrm{CH} = \frac{\text{Cash}}{\text{Total assets}}$$
- SIZE: Natural logarithm of sales used as a firm size proxy
$$\mathrm{SIZE} = \ln\,(\text{Total sales})$$
- LREV: Logarithmic revenues

$$\text{LREV} = \ln(\text{Total revenues})$$

- LEV: Leverage-debt ratio

$$\text{LEV} = \frac{\text{Total debt}}{\text{Total assets}}$$

- BL: Book leverage

$$\text{BL} = \frac{\text{Total debt}}{\text{Total debt} + \text{Total equity}}$$

- PR: Profitability ratio
  Earnings before interest, taxes, depreciation, and amortization (EBITDA), is a measure of a company's overall financial performance and is used as an alternative to net income.

$$\text{PR} = \frac{\text{EBITDA}}{\text{Total assets}}$$

- ROA: Return on assets
  A financial ratio that indicates how profitable a company is in relation to its total assets.

$$\text{ROA} = \frac{\text{Net income}}{\text{Total assets}}$$

- TQ: Tobin's Q
  It equals the market value of a company divided by its assets' replacement cost.

$$\text{TQ} = \frac{\text{Market value}}{\text{Total liabilities} + \text{Total equity}}$$

- RD: Environmental R&D costs
- ESG: ESG score on a [0-1] scale

A correlation matrix has been generated for the aforementioned variables (Figure 15). Variables with values closer to 1 or -1 have been primarily examined for the models. However, the correlation matrix is only an indicator of values that may fit the model. Other variables have also been tested, and the final models have been constructed with the trial-and-error method.

	LMV	LRISK	AT	CURR	TANG	CH	SIZE	LREV	LEV	BL	PR	ROA	TQ	RD	ESG
LMV	1														
LRISK	-0.73	1													
AT	0.14	-0.42	1												
CURR	-0.24	-0.11	0.40	1											
TANG	0.04	0.25	-0.59	-0.83	1										
CH	-0.22	-0.08	0.17	0.87	-0.62	1									
SIZE	0.93	-0.67	0.31	-0.23	-0.01	-0.26	1								
LREV	0.93	-0.67	0.31	-0.23	-0.01	-0.26	1.00	1							
LEV	-0.26	0.47	-0.24	-0.39	0.32	-0.36	-0.15	-0.15	1						
BL	-0.22	0.43	-0.24	-0.41	0.31	-0.38	-0.11	-0.11	0.98	1					
PR	0.21	-0.32	0.13	-0.23	0.27	-0.19	0.21	0.21	-0.01	0.00	1				
ROA	0.21	-0.44	0.21	0.07	-0.06	0.06	0.15	0.15	-0.46	-0.44	0.54	1			
TQ	0.46	-0.54	0.24	0.20	-0.18	0.19	0.22	0.22	-0.38	-0.38	0.28	0.26	1		
RD	0.58	-0.40	0.19	-0.10	-0.08	-0.11	0.63	0.63	-0.12	-0.09	-0.11	0.03	0.04	1	
ESG	0.77	-0.53	0.16	-0.09	-0.12	-0.06	0.83	0.83	-0.11	-0.06	0.04	0.09	0.08	0.60	1

Figure 15 Correlation matrix. Green represents positive correlation and red negative correlation. The darker colors represent a higher absolute value.

3.2.1 Market value model

The market value of a firm is represented by its market capitalization, which occurs by multiplying the number of the issued ordinary shares by the share price. The utilization of the market cap deems appropriate given that all the examined companies are publicly traded, and, thus, their market value is defined by the stock exchange. The regression model developed uses the natural logarithm of the market cap as the dependent variable (LMV). The rationale behind this decision is that the extremely high numerical values of the market cap (billions of USD) would significantly reduce the usableness and practicability of the model, whereas the logarithmic values lead to beta coefficients that are easier to interpret.

$$\text{LMV} = \ln(\text{Market Cap}) = \ln\,(\#\text{ ordinary share } \cdot \text{share price})$$

The model attempts to assess and quantify the impact of ESG scores on the market value of US energy companies. For this purpose, the ESG score is used as a predictor in the regression. Apart from the ESG element, the regression model needs to employ further independent variables to make accurate predictions for the firm's market value. For this purpose, the firm's total debt and revenues are selected. Both measures are easy-to-use since they are reported on the balance sheet and the income statement respectively and have an impact on the firm's market value. The amount of debt undertaken is a crucial financing decision that the company's shareholders, as well as the overall stock market, need to consider when investing. Similarly, the revenues express the company's profitability and affect the number of dividends that the firm pays to the shareholders. Many studies have used a debt-over-assets ratio as well as the natural logarithm of total revenues for modeling a firm's financial performance and market value (Ahmad et al., 2021; Alareeni & Hamdan, 2020; Elsayed & Paton, 2005; Velte, 2017; Wong et al., 2021). Under the above perspective, the present model employs the following variables to account for the effect of debt and revenues on the market value of US energy companies.

$$\text{LEV} = \frac{\text{Total debt}}{\text{Total assets}}$$

$$\text{LREV} = \ln\,(\text{Total revenues})$$

The regression model constructed can be expressed as:

$$LMV = c + \beta_1 \cdot LREV + \beta_2 \cdot LEV + \beta_3 \cdot ESG + \varepsilon$$

Descriptive statistics

The mean value of LMV is 21.437, which suggests that the mean market value of a US NYSE-inducted energy firm, for the examined period, is approximately $2.04 billion. A similar pattern is observed for the distribution of logarithmic revenues, which has a mean value of 21.172 but is significantly more leptokurtic (kurtosis $\gg$ 3). The firm's leverage cannot take negative values since the LEV variable is calculated as the ratio of debt over total assets, whose minimum value is 0 (no debt). Finally, the ESG scores can range between 0 and 1, while the present dataset has a mean of 0.374 and a maximum of 0.881. The distribution is positively skewed ($\alpha^3 = 0.61$) and slightly platykurtic ($\alpha^4 = 2.38$).

The descriptive statistics of the model's variables are summarized in Table 3.

	LMV	LREV	LEV	ESG
Mean	21.437	21.172	0.344	0.374
Median	21.225	20.959	0.322	0.332
Standard deviation	1.804	1.955	0.234	0.201
Minimum	16.715	0.260	0.000	0.045
Maximum	26.649	26.356	2.784	0.881
Skewness	0.431	-1.328	2.166	0.610
Kurtosis	2.796	20.402	20.114	2.384

Table 3 Market value model - Descriptive statistics.

Regression results

The regression results are summarized in Table 4.

Dependent variable: LMV
Observations: 429

Variable	β	S.E.	t-stat.	Probability	VIF
C	6.261	0.623	10.044	0.0000	-
LREV	0.700	0.031	22.314	0.0000	1.690
LEV	-0.529	0.228	-2.327	0.0204	1.006
ESG	1.717	0.285	6.029	0.0000	1.682
R^2	0.740			SS_{RES}	353.562
R^2_{ADJ}	0.738			F-stat.	402.889
S.E.	0.912			Prob. (F-stat.)	0.0000

Table 4 Market value model – Regression results.

The model has a significantly increased R^2 value, that exceeds 70%, which is not relatively common in econometric regressions. Consequently, it can be concluded that the model has a very good fitting and that the 3 independent variables provide a reliable estimation for the firm's market value. At the same time, the adjusted R^2 does not deviate from the R^2, signifying that there is no spurious increase of the R^2 due to the inclusion of redundant variables. This conclusion is supported by the t-statistic and the respective probabilities, which are below the 5% threshold, suggesting that all variables are statistically significant at the 5% confidence level. As far as multicollinearity is concerned, the Variance Inflation Factors (VIF) are all below the usual thresholds of 5 and 10, verifying that the model does not have multicollinearity.

Once the model's fitting, significance, and multicollinearity are assessed, it is important that the coefficients are analyzed, as they quantify the relationships among the regressors and the dependent variable. Both the revenues and the ESG scores appear to positively affect the market value as their coefficients have positive signs, while the leverage variable has a negative coefficient and, consequently, a negative impact on the market value. Focusing on the impact of the ESG, the effect of an 0.01 (1%) unit increase of the score on the firm's market value can be calculated as follows:

Assuming that all other variables remain constant and that LMV' is the new logarithmic market value:

$$\mathrm{LMV} = \mathrm{z} = \mathrm{c} + \beta_1 \cdot \mathrm{LREV} + \beta_2 \cdot \mathrm{LEV} + \beta_3 \cdot \mathrm{ESG}$$

$$\mathrm{LMV}' = \mathrm{z}' = \mathrm{c} + \beta_1 \cdot \mathrm{LREV} + \beta_2 \cdot \mathrm{LEV} + \beta_3 \cdot (\mathrm{ESG} + 0.01)$$

The change in the market value can expressed as:

$$\delta\mathrm{MV} = \frac{e^{z'} - e^{z}}{e^{z}} = \frac{e^{z'}}{e^{z}} - 1 = e^{\beta_3 \cdot 0.01} - 1 = e^{0.017} - 1 = 1.73\%$$

Therefore, a 0.01 absolute increase in the ESG score causes a 1.73% increase in the absolute market value of a firm. Considering the average LMV value of 21.437, it can be derived that the corresponding average market value is $2.041 billion. As a result, an averagely valued company that manages to increase its ESG score by 0.01 units (1%) experiences a $35.2 million increase in its market value.

Residual diagnostics

The residuals of the regression model should be tested for normality and homoskedasticity to assess the unbiasedness, consistency, and efficiency of the OLS estimators. The descriptive statistics of the residuals are presented in Table 5.

Mean	0.000
Median	-0.007
Standard deviation	0.909
Minimum	-2.610
Maximum	2.673
Skewness	-0.084
Kurtosis	2.726

Table 5 Market value model – Residual diagnostics.

The normality of the residuals is assessed by the Jarque-Bera test. The null and alternative hypotheses are stated:

- H_0: The residuals are normally distributed.
- H_a: The residuals are not normally distributed.

The Jarque-Bera statistic follows a chi-square distribution with 2 degrees of freedom. At the 5% significance level:

$$\chi^2_{(2)\mathrm{crit}} = 5.99 > 1.85 = \mathrm{JB}$$

The null hypothesis is, therefore, accepted (fail to reject), and the distribution of the error terms is normal. A histogram of the residuals along with a normal distribution curve is presented in Figure 16. It can be observed that the normal curve fits the histogram sufficiently, despite the slightly negative skewness, depicted by the longer and flatter left tail of the histogram, and the slightly negative excess kurtosis, depicted by the slightly platykurtic shape of the histogram.

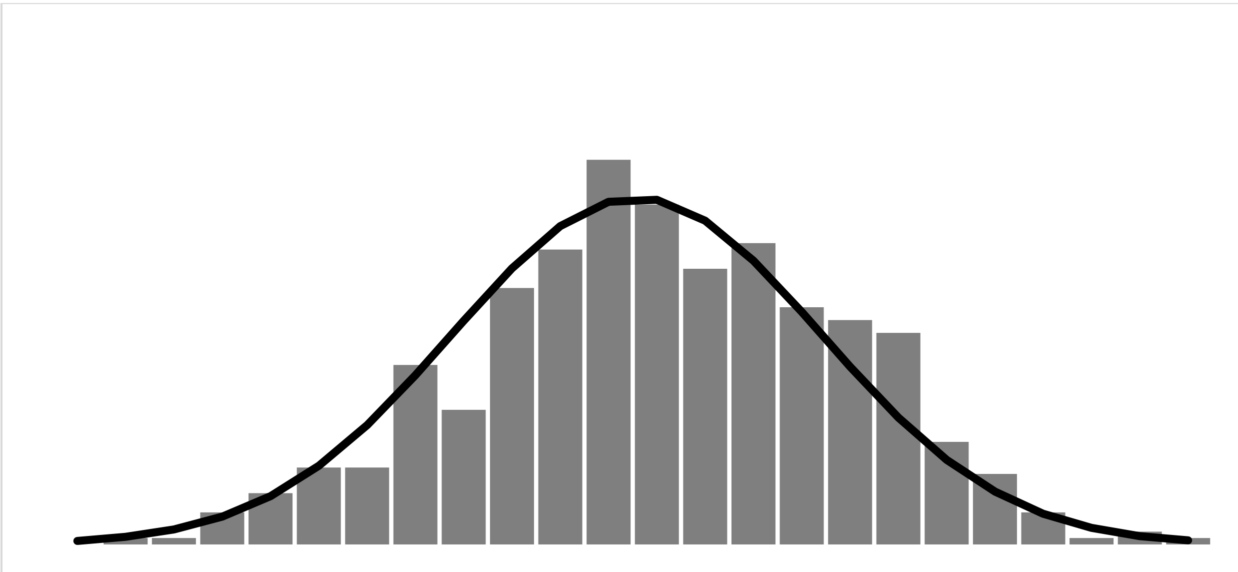


Figure 16 Market value model - Histogram of the residuals on a normal distribution curve.

The presence of heteroskedasticity is assessed by the White test. Initially, the squared residuals are regressed over the independent variables, their square values as well as their cross-products.

The results of the regression are summarized in Table 6.

Dependent variable: ε^2
Observations: 429

Variable	β	S.E.	t-stat.	Probability
C	14.112	8.648	1.632	0.1034
LREV	-1.690	0.857	-1.972	0.0493
LEV	0.842	4.792	0.176	0.8606
ESG	22.946	5.825	3.939	0.0001
LREV ^{2}	0.050	0.021	2.335	0.0200
LEV ^{2}	-0.802	0.773	-1.038	0.2997
ESG ^{2}	2.362	1.845	1.280	0.2011
LREV·LEV	0.029	0.244	0.119	0.9049
LREV·ESG	-1.142	0.301	-3.800	0.0002
LEV·ESG	-1.597	2.224	-0.718	0.4731
R^2	0.078	SS_{RES}		463.710
R^2_{ADJ}	0.058	F-stat.		3.924
S.E.	1.052	Prob. (F-stat.)		0.000

Table 6 Market value model – White test results.

The null and alternative hypotheses are stated:

- H_0: $\beta_1 = \beta_2 = \cdots = \beta_9 = 0$ (homoskedasticity).
- H_a: At least one $\beta \neq 0$ (heteroskedasticity).

The auxiliary regression has 9 degrees of freedom, therefore $n \cdot R^2 \sim \chi^2_{(9)}$. At the 5% significance level:

$$\chi^2_{(9)crit} = 16.92 < 33.35 = n \cdot R^2$$

Therefore, the null hypothesis is rejected, and the residuals of the model suffer from heteroskedasticity, which affects the efficiency of the estimators. The White correction is applied to remedy the heteroskedastic error terms. The correction concerns the biased standard errors and has no impact on the regression coefficients.

The White-corrected regression results are presented in Table 7.

Dependent variable: LMV
Observations: 429
Huber-White-Hinkley (HC1) heteroskedasticity consistent SE and covariance

Variable	β	S.E.	t-stat.	Probability	VIF
C	6.261	0.678	9.228	0.0000	-
LREV	0.700	0.036	19.660	0.0000	2.719
LEV	-0.529	0.214	-2.478	0.0136	1.004
ESG	1.717	0.315	5.449	0.0000	2.715
R^2	0.740			SS_{RES}	353.562
R^2_{ADJ}	0.738			F-stat.	402.889
S.E.	0.912			Prob. (F-stat.)	0.0000

Table 7 Market value model - Regression results after White correction.

A comparison between Table 4 and Table 7 verifies that only the standard errors of the coefficients are corrected to allow for solid hypothesis testing under the presence of heteroskedasticity. Correspondingly, the t-statistics and their probabilities are also altered. As far as the variance inflation factors are concerned, they are still below the "5" threshold, indicating the absence of multicollinearity from the regression.

Forecast

The regression models are constructed based on observations for the 2015-2019 period. The ESG score model is employed to make a forecast for 2020. Overall, 89 forecasts are made, as 33 companies fail to provide substantial data for 2020.

The statistics employed for evaluating the forecast are shown in Table 8.

MAE	RMAE	MSE	RMSE
0.955	0.977	1.486	1.219
Theil's U	Bias	Variance	Covariance
0.029	0.282	0.099	0.620

Table 8 Market value model – Forecast results.

The model has a very satisfactory forecasting ability as the Theil's U is significantly low, approaching its minimum value. The covariance proportion, which is slightly increased, expresses the unsystematic error and is regarded as a less problematic component.

3.2.2 Market value alternative, dummy model

An alternative model with dummy variables for the market value model is also examined. The model used is given as:

$$\mathrm{LMV} = \mathrm{c} + \beta_1 \cdot \mathrm{LREV} + \beta_2 \cdot \mathrm{LEV} + \beta_3 \cdot \mathrm{HSD} + \beta_4 \cdot \mathrm{LSD} + \varepsilon$$

This model replaces the ESG score variable with the two dummy variables HSD (High Score Dummy) and LSD (Low Score Dummy) (Limkriangkrai et al., 2017b). The definition of the ESG dummies relies on the subscores of the 3 ESG components:

- ENV: environmental score.
- SOC: social score.
- GOV: governance score.

The dummy variables are defined as follows:

- If at least two of the three individual ESG scores are greater than 75% (B+ rating and above), the HSD is equal to 1. In any other case, it is equal to 0.
- If at least two of the three individual ESG scores are lesser than 25% (D+ rating and below), the LSD is equal to 1. In any other case, it is equal to 0.

Regression results

The regression results are summarized in Table 9.

Dependent variable: LMV
Observations: 429

Variable	β	S.E.	t-stat.	Probability	VIF
C	5.994	0.662	9.060	0.0000	-
LREV	0.743	0.030	25.134	0.0000	1.470
LEV	-0.476	0.230	-2.068	0.0393	1.010
HSD	0.883	0.189	4.679	0.0000	1.170
LSD	-0.238	0.105	-2.274	0.0234	1.324
R^2	0.735			SS_{RES}	359.930
R^2_{ADJ}	0.734			F-stat.	294.247
S.E.	0.921			Prob. (F-stat.)	0.0000

Table 9 Market value alternative dummy model – Regression results.

The model has a significantly increased R^2 value that exceeds 70% and is not relatively common in econometric regressions. Consequently, it can be concluded that the model has a very good fitting and that the three independent variables provide a reliable estimation for the firm's market value. At the same time, the adjusted R^2 does not deviate from the R^2, signifying that there is no spurious increase of the R^2 due to the inclusion of redundant variables. This conclusion is supported by the t-statistic and the respective probabilities, which are below the 5% threshold, suggesting that all variables are statistically significant at the 5% confidence level. As far as multicollinearity is concerned, the Variance Inflation Factors (VIF) are all below the usual thresholds of 5 and 10, verifying that the model does not suffer from multicollinearity.

Once the model's fitting, significance, and multicollinearity are assessed, it is important that the coefficients are analyzed and discussed as they are the ones that quantify the relationships among the regressors and the dependent variable. Both the revenues and the HSD dummy appear to positively affect the market value as their coefficients have positive signs, while LEV and LSD have a negative coefficient and, consequently, a negative impact on the market value. Focusing on the impact of the dummies, the following cases are examined:

Achieving an over 75% score in at least two of the ESG subcategories and, assuming that all other variables remain constant and that LMV′ is the new logarithmic market value:

$$\mathrm{LMV} = \mathrm{z} = \mathrm{c} + \beta_1 \cdot \mathrm{LREV} + \beta_2 \cdot \mathrm{LEV} + \beta_3 \cdot 0 + \beta_4 \cdot \mathrm{LSD}$$

$$\mathrm{LMV}' = \mathrm{z}' = \mathrm{c} + \beta_1 \cdot \mathrm{LREV} + \beta_2 \cdot \mathrm{LEV} + \beta_3 \cdot 1 + \beta_4 \cdot \mathrm{LSD}$$

The change in the market value can be expressed as:

$$\delta\mathrm{MV} = \frac{\mathrm{e}^{\mathrm{z}'} - \mathrm{e}^{\mathrm{z}}}{\mathrm{e}^{\mathrm{z}}} = \frac{\mathrm{e}^{\mathrm{z}'}}{\mathrm{e}^{\mathrm{z}}} - 1 = \mathrm{e}^{\beta_3} - 1 = \mathrm{e}^{0.883} - 1 = 142\%$$

On the other hand, if the scores fall below 25% score in at least two of the ESG subcategories, then, assuming that all other variables remain constant and that LMV′ is the new logarithmic market value:

$$\mathrm{LMV} = \mathrm{z} = \mathrm{c} + \beta_1 \cdot \mathrm{LREV} + \beta_2 \cdot \mathrm{LEV} + \beta_3 \cdot \mathrm{HSD} + \beta_4 \cdot 0$$

$$\mathrm{LMV}' = \mathrm{z}' = \mathrm{c} + \beta_1 \cdot \mathrm{LREV} + \beta_2 \cdot \mathrm{LEV} + \beta_3 \cdot \mathrm{HSD} + \beta_4 \cdot 1$$

The change in the market value can be expressed as:

$$\delta\mathrm{MV} = \frac{\mathrm{e}^{\mathrm{z}'} - \mathrm{e}^{\mathrm{z}}}{\mathrm{e}^{\mathrm{z}}} = \frac{\mathrm{e}^{\mathrm{z}'}}{\mathrm{e}^{\mathrm{z}}} - 1 = \mathrm{e}^{\beta_4} - 1 = \mathrm{e}^{-0.238} - 1 = -21.2\%$$

The results can be interpreted as follows. A company that succeeds in increasing its ESG scores above 75% in at least two sub-categories while maintaining constant revenues and leverage can more than double its market value. On the other hand, if it fails to meet high, or even mediocre, ESG standards, the market value may reduce by approximately 20%. The current findings support the hypothesis that modern investors significantly value a firm's ESG performance.

Residual diagnostics

The residuals of the regression model should be tested for normality and homoskedasticity to assess the unbiasedness, consistency, and efficiency of the OLS estimators. The descriptive statistics of the residuals are presented in Table 10.

Mean	0.000
Median	-0.030
Standard deviation	0.917
Minimum	-2.975
Maximum	2.371
Skewness	-0.098
Kurtosis	2.731

Table 10 Market value alternative dummy model – Residual diagnostics.

The Jarque-Bera test assesses the normality of the residuals. The null and alternative hypotheses are stated:

- H_0: The residuals are normally distributed.
- H_a: The residuals are not normally distributed.

The Jarque-Bera statistic follows a chi-square distribution with 2 degrees of freedom. At the 5% significance level:

$$\chi^2_{(2)crit} = 5.99 > 1.99 = JB$$

Therefore, the null hypothesis is accepted (fail to reject), and the distribution of the error terms is normal. A histogram of the residuals and a normal distribution curve are presented in Figure 17. It can be observed that the normal curve fits the histogram sufficiently, despite the slightly negative skewness depicted by the longer and flatter left tail of the histogram, and the slightly negative excess kurtosis, depicted by the slightly platykurtic shape of the histogram.

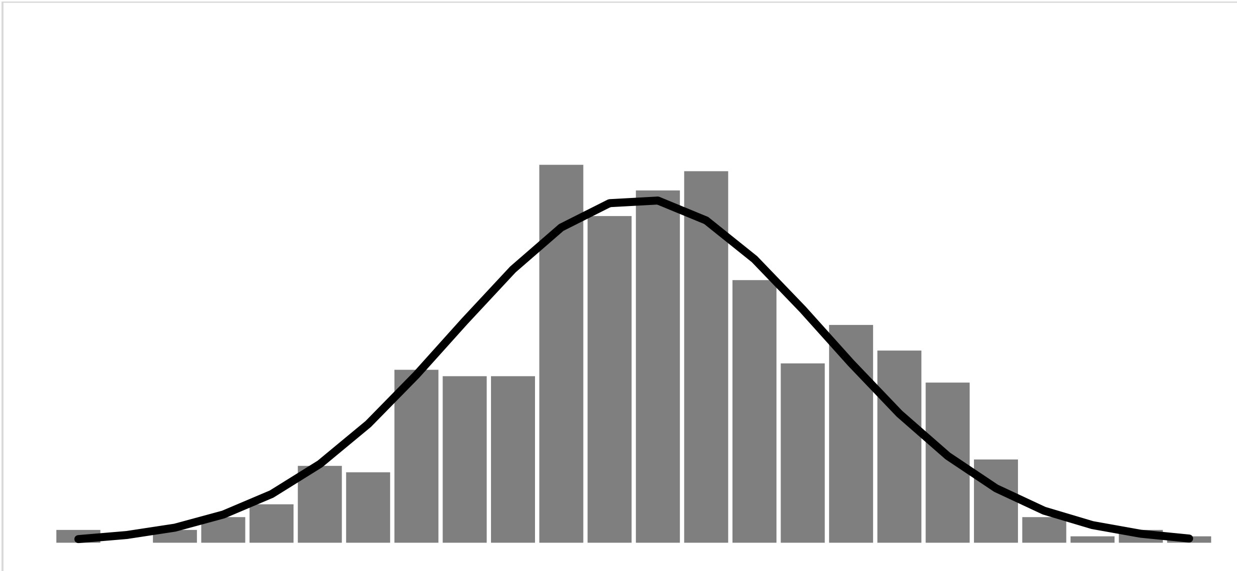


Figure 17 Market value alternative dummy model - Histogram of the residuals on a normal distribution curve.

The presence of heteroskedasticity is assessed by the White test. Initially, the squared residuals are regressed over the independent variables, their square values as well as their cross-products. The results of the regression are summarized in Table 11.

Dependent variable: ε^2
Observations: 429

Variable	β	S.E.	t-stat.	Probability
C	-9.443	9.942	-0.950	0.3427
LREV	0.849	0.883	0.961	0.3372
LEV	0.815	5.237	0.156	0.8763
LREV ^{2}	-0.017	0.020	-0.876	0.3816
LEV ^{2}	-0.998	0.808	-1.236	0.2172
HSD ^{2}	-0.009	0.240	-0.038	0.9698
LSD ^{2}	2.305	5.301	0.435	0.6639
LREV·LEV	0.187	2.072	0.090	0.9283
LREV·HSD	-0.124	0.212	-0.586	0.5580
LREV·LSD	-0.017	0.098	-0.172	0.8639
LEV·HSD	-0.798	1.988	-0.401	0.6883
LEV·LSD	0.638	0.705	0.905	0.3662
R^2	0.059	SS_{RES}		491.804
R^2_{ADJ}	0.034	F-stat.		2.379
S.E.	1.086	Prob. (F-stat.)		0.007

Table 11 Market value alternative dummy model – White test results.

The null and alternative hypotheses are stated:

- $H_0: \beta_1 = \beta_2 = \cdots = \beta_9 = 0$ (homoskedasticity).
- H_a: At least one $\beta \neq 0$ (heteroskedasticity).

The auxiliary regression has 11 degrees of freedom, therefore $n \cdot R^2 \sim \chi^2_{(9)}$. At the 5% significance level:

$$\chi^2_{(11)crit} = 19.68 < 25.33 = n \cdot R^2$$

Therefore, the null hypothesis is rejected, and the residuals of the model suffer from heteroskedasticity, which affects the efficiency of the estimators. The White correction is applied to remedy the heteroskedastic error terms. The correction concerns the biased standard errors and has no impact on the coefficients of the regression.

The White-corrected regression results are presented in Table 12.

Dependent variable: LMV
Observations: 429
Huber-White-Hinkley (HC1) heteroskedasticity consistent SE and covariance

Variable	β	S.E.	t-stat.	Probability	VIF
C	5.994	0.659	9.090	0.0000	-
LREV	0.743	0.030	24.773	0.0000	2.252
LEV	-0.476	0.212	-2.243	0.0254	1.014
HSD	0.883	0.129	6.817	0.0000	1.770
LSD	-0.238	0.107	-2.227	0.0265	1.572
R^2	0.735		SS_{RES}		359.930
R^2_{ADJ}	0.733		F-stat.		294.247
S.E.	0.921		Prob. (F-stat.)		0.0000

Table 12 Market value alternative dummy model - Regression results after White correction.

A comparison between Table 9 and Table 12 verifies that only the standard errors of the coefficients are corrected to allow for solid hypothesis testing under the presence of heteroskedasticity. Correspondingly, the t-statistics and their probabilities are also altered. As far as the variance inflation factors are concerned, they are still below the "5" threshold, indicating the absence of multicollinearity from the regression.

Forecast

The statistics employed for evaluating the forecast are shown in Table 13.

MAE	RMAE	MSE	RMSE
0.914	0.956	1.370	1.170
Theil's U	Bias	Variance	Covariance
0.028	0.249	0.111	0.640

Table 13 Market value alternative dummy model – Forecast results.

The model's results are similar to the ones examined in the original model. The model has a very satisfactory forecasting ability as the Theil's U is significantly low, approaching its minimum value. The covariance proportion, which is slightly increased, expresses the unsystematic error and is regarded as a less problematic component.

3.2.3 Risk model

Various theories and methodologies for approximating the risk of a company have been introduced. A common way to evaluate the total risk that a publicly-traded firm faces is through the volatility of its share price, which reflects all fluctuations that either benefit or harm the company. The study utilizes the annualized standard deviation of the daily stock returns as a proxy of the total risk that the examined US energy companies are exposed to (Sassen et al., 2016b). The daily stock return R_t is calculated as the natural logarithm of the current stock price over the stock price of the previous trading day.

$$R_t = \ln{(P_t/P_{t-1})}$$

Once all daily stock returns have been collected, their standard deviation is calculated and annualized by multiplying it by the square root of the total trading days of the examined year.

$$\text{Risk} = \text{st.dev}(R_t) \cdot \sqrt{\#\ \text{trading days}}$$

This approach estimates the company's annual risk, which is necessary given that the regression models are constructed on an annual frequency. The total risk of the first calendar year during which each firm entered the NYSE, is not calculated. This omission is because during their first year in the stock exchange, companies are traded for significantly lesser days, which could incur bias in the risk estimation.

The developed regression model uses the calculated risk's natural logarithm as the dependent variable (LRISK).

The regression model seeks to define and understand how the risk that the US energy firms face can be affected by their ESG ratings. For this purpose, the logarithmic ESG score (LESG) is used as a predictor in the regression. Apart from the ESG element, the regression model needs to employ further independent variables to make accurate predictions for the firm's market value. For this purpose, the firm's total debt and Return on Assets (ROA) are selected. Both measures are easy-to-use since the amount of debt is reported on the balance sheet, and return on assets can be easily calculated as the net income (income statement) over total asset (balance sheet) ratio. The amount of debt undertaken is a crucial financing decision that the company's shareholders, as well as the overall stock market, need to consider when investing; similarly, the ROA expresses the profitability of the company in relation to its assets and affects the number of dividends that the firm pays to the shareholders. Many studies have used a debt-over-assets ratio as well as the ROA metric for modelling a firm's price volatility and risk (Sassen et al., 2016; Shakil, 2020). The present model, under the above perspective, employs the following variables to account for the effect of debt and ROA on the risk faced by the US energy companies.

$$\mathrm{LEV} = \frac{\text{Total debt}}{\text{Total assets}}$$

$$\mathrm{ROA} = \frac{\text{Net income}}{\text{Total assets}}$$

The regression model constructed can be expressed as:

$$\mathrm{LRISK} = \mathrm{c} + \beta_1 \cdot \mathrm{LEV} + \beta_2 \cdot \mathrm{ROA} + \beta_3 \cdot \mathrm{ESG} + \varepsilon$$

Descriptive statistics

The mean value of LRISK is -0.714, which suggests that the mean annual market risk of a US NYSE-inducted energy firm for the examined period is approximately 48.97%. The distribution of the logarithmic risk is mesokurtic and has slightly positive skewness. The firm's leverage cannot take negative values since the LEV variable is calculated as the debt ratio over total assets, whose minimum value is 0 (no debt). The mean return on assets for the examined dataset is -2.1%, while the standard deviation is greater than 23%. The ROA distribution is positively skewed and severely leptokurtic (38.591≫3). Finally, the ESG scores can range between 0 and 1, which suggests that the LESG is non-positive. The mean LESG value is -1.141, which reflects a 0.32 ESG score, and the distribution is negatively skewed ($\alpha^3 = -0.28$) and slightly platykurtic ($\alpha^4 = 2.35$).

The descriptive statistics of the model's variables are summarized in Table 14.

	LRISK	LEV	ROA	LESG
Mean	-0.714	0.344	-0.021	-1.141
Median	-0.759	0.322	0.001	-1.102
Standard deviation	0.511	0.234	0.235	0.581
Minimum	-2.171	0.000	-1.286	-3.110
Maximum	0.816	2.784	2.554	-0.127
Skewness	0.331	2.166	2.736	-0.281
Kurtosis	2.967	20.114	38.591	2.348

Table 14 Risk model - Descriptive statistics.

Regression results

The regression results are summarized in Table 15.

Dependent variable: LRISK
Observations: 409

Variable	β	S.E.	t-stat.	Probability	VIF
C	-0.761	0.044	-17.331	0.0000	-
LEV	0.380	0.084	4.499	0.0000	1.054
ROA	-0.939	0.128	-7.312	0.0000	1.052
LESG	-0.648	0.080	-8.067	0.0000	1.003
R^2	0.291			SS_{RES}	42.791
R^2_{ADJ}	0.286			F-stat.	55.367
S.E.	0.325			Prob. (F-stat.)	0.0000

Table 15 Risk model – Regression results.

The model does not have a very high R^2 value, a common phenomenon in econometric regressions. Consequently, it can be concluded that the model has a satisfactory fitting and that the three independent variables provide a sufficient estimation for the firm's risk. At the same time, the adjusted R^2 does not deviate from the R^2, signifying that there is no spurious increase of the R^2 due to the inclusion of redundant variables. This conclusion is supported by the t-statistic and the respective probabilities, which are below the 5% threshold, suggesting that all variables are statistically significant at the 5% confidence level. As far as multicollinearity is concerned, the Variance Inflation Factors (VIF) are all below the usual thresholds of 5 and 10, verifying that the model does not suffer from multicollinearity.

Once the model's fitting, significance, and multicollinearity are assessed, it is vital that the coefficients are analyzed and discussed as they are the ones that quantify the relationships among the regressors and the dependent variable. Both the ROA and LESG variables appear to negatively affect the firm's risk as their βs have negative signs, while the leverage variable has a positive coefficient and, consequently, a positive impact on the risk. Focusing on the impact of the ESG, the effect of a 10% increase of the score on the firm's risk can be calculated as follows:

A 10% increase of the ESG score corresponds to an $\ln(1.1) = 0.095$ absolute increase of the LESG

Assuming that all other variables remain constant and that LRISK' is the new logarithmic risk:

$$\mathrm{LRISK} = \mathrm{z} = \mathrm{c} + \beta_1 \cdot \mathrm{LEV} + \beta_2 \cdot \mathrm{ROA} + \beta_3 \cdot \mathrm{LESG}$$

$$\mathrm{LRISK}' = \mathrm{z}' = \mathrm{c} + \beta_1 \cdot \mathrm{LEV} + \beta_2 \cdot \mathrm{ROA} + \beta_3 \cdot (\mathrm{LESG} + 0.095)$$

The change in the risk can expressed as:

$$\delta\mathrm{RISK} = \frac{\mathrm{e}^{\mathrm{z}'} - \mathrm{e}^{\mathrm{z}}}{\mathrm{e}^{\mathrm{z}}} = \frac{\mathrm{e}^{\mathrm{z}'}}{\mathrm{e}^{\mathrm{z}}} - 1 = \mathrm{e}^{\beta_3 \cdot 0.095} - 1 = \mathrm{e}^{-0.062} - 1 = -5.99\%$$

Therefore, a 10% increase in the ESG score causes a 5.99% decrease in the annualized firm risk. Considering the average LRISK value of -0.714, it can be derived that the corresponding average risk is 48.97%. As a result, a company of average annual risk that manages to increase its ESG score by 10% experiences a reduction of its risk by 2.93 percentage units.

Residual diagnostics

The residuals of the regression model should be tested for normality and homoskedasticity to assess the unbiasedness, consistency, and efficiency of the OLS estimators. The descriptive statistics of the residuals are presented in Table 16.

Mean	0.000
Median	0.005
Standard deviation	0.324
Minimum	-1.019
Maximum	1.019
Skewness	-0.104
Kurtosis	3.394

Table 16 Risk model – Residual diagnostics.

The Jarque-Bera test assesses the normality of the residuals. The null and alternative hypotheses are stated:

- H_0: The residuals are normally distributed.
- H_a: The residuals are not normally distributed.

The Jarque-Bera statistic follows a chi-square distribution with 2 degrees of freedom. At the 5% significance level:

$$\chi^2_{(2)crit} = 5.99 > 3.38 = JB$$

Therefore, the null hypothesis is accepted (fail to reject), and the distribution of the error terms is normal. A histogram of the residuals and a normal distribution curve are presented in Figure 18. It can be observed that the normal curve fits the histogram sufficiently, despite the slightly negative skewness depicted by the longer and flatter left tail of the histogram, and the slightly positive excess kurtosis, depicted by the slightly leptokurtic shape of the histogram.

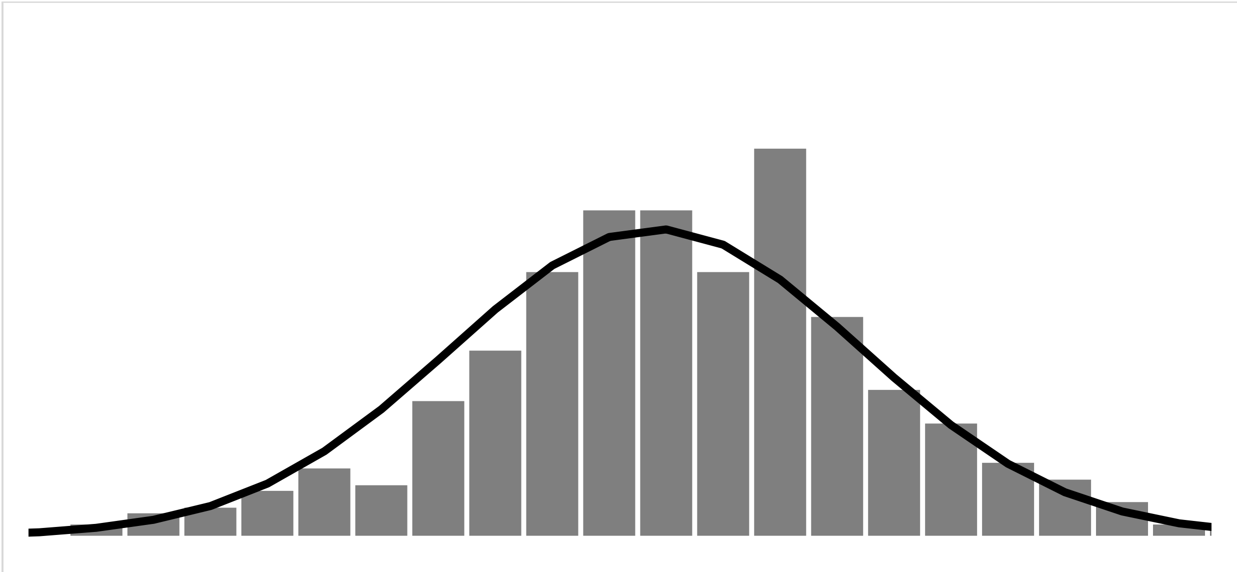


Figure 18 Risk model - Histogram of the residuals on a normal distribution curve.

The White test assesses the presence of heteroskedasticity. Initially, the squared residuals are regressed over the independent variables, their square values, and their cross-products. The results of the regression are summarized in Table 17.

Dependent variable: ε^2
Observations: 409

Variable	β	S.E.	t-stat.	Probability
C	0.094	0.048	1.984	0.0479
LEV	0.201	0.141	1.425	0.1550
ROA	-0.118	0.164	-0.720	0.4721
LESG	-0.295	0.215	-1.374	0.1702
LEV^2	-0.048	0.126	-0.377	0.7061
ROA^2	0.300	0.228	1.311	0.1905
$LESG^2$	0.332	0.207	1.608	0.1086
LEV·ROA	0.469	0.273	1.721	0.0860
LEV·LESG	0.027	0.262	0.104	0.9169
ROA·LESG	0.185	0.356	0.520	0.6034
R^2	0.049	SS_{RES}		10.187
R^2_{ADJ}	0.028	F-stat.		2.305
S.E.	0.160	Prob. (F-stat.)		0.015

Table 17 Risk model – White test results.

The null and alternative hypotheses are stated:

- H_0: $\beta_1 = \beta_2 = \cdots = \beta_9 = 0$ (homoskedasticity).
- H_a: At least one $\beta \neq 0$ (heteroskedasticity).

The auxiliary regression has 9 degrees of freedom, therefore $n \cdot R^2 \sim \chi^2_{(9)}$. At the 5% significance level:

$$\chi^2_{(9)crit} = 16.92 < 20.22 = n \cdot R^2$$

Therefore, the null hypothesis is rejected, and the model's residuals suffer from heteroskedasticity, which affects the efficiency of the estimators. The White correction is applied to remedy the heteroskedastic error terms. The correction concerns the biased standard errors and has no impact on the regression coefficients.

The White-corrected regression results are presented in Table 18.

Dependent variable: LRISK
Observations: 409
Huber-White-Hinkley (HC1) heteroskedasticity consistent SE and covariance

Variable	β	S.E.	t-stat.	Probability	VIF
C	-0.761	0.041	-18.354	0.0000	-
LEV	0.380	0.092	4.149	0.0000	1.122
ROA	-0.939	0.140	-6.700	0.0000	1.120
LESG	-0.648	0.084	-7.739	0.0000	1.002
R^2	0.291		SS_{RES}		42.791
R^2_{ADJ}	0.286		F-stat.		55.367
S.E.	0.325		Prob. (F-stat.)		0.0000

Table 18 Risk model - Regression results after White correction.

A comparison between Table 15 and Table 18 verifies that only the standard errors of the coefficients are corrected to allow for solid hypothesis testing under the presence of heteroskedasticity. Correspondingly, the t-statistics and their probabilities are also altered. As far as the variance inflation factors are concerned, they are almost minimum (slightly greater than 1), indicating the absence of multicollinearity from the regression.

Forecast

The regression models are constructed based on observations for the 2015-2019 period. The ESG score model is employed to make a forecast for 2020. Overall, 89 forecasts are made, as 33 companies fail to provide substantial data for 2020.

The statistics employed for evaluating the forecast are shown inTable 19.

MAE	RMAE	MSE	RMSE
0.539	0.734	0.379	0.615
Theil's U	Bias	Variance	Covariance
0.392	0.754	0.101	0.145

Table 19 Risk model – Forecast results.

The model has a mediocre forecasting ability as Theil's U is slightly lower than 0.5. The high bias proportion also verifies the reduced forecasting performance of the model. The variance and covariance proportions, however, are significantly lower, suggesting that no revision of the model is necessary.

3.2.4 Risk alternative, dummy model

An alternative model with dummy variables is also examined. The model used is given as:

$$LMV = c + \beta_1 \cdot LEV + \beta_2 \cdot ROA + \beta_3 \cdot HSD + \beta_4 \cdot LSD + \varepsilon$$

This model replaces the ESG score variable with the two dummy variables HSD (High Score Dummy) and LSD (Low Score Dummy) (Sassen et al., 2016). The definition of the ESG dummies relies on the subscores of the 3 ESG components:

- ENV: environmental score.
- SOC: social score.
- GOV: governance score.

The dummy variables are defined as follows:

- If at least two of the three individual ESG scores are greater than 75% (B+ rating and above), the HSD is equal to 1. In any other case, it is equal to 0.
- If at least two of the three individual ESG scores are lesser than 25% (D+ rating and below), the LSD is equal to 1. In any other case, it is equal to 0.

Regression results

The regression results are summarized in Table 20.

Dependent variable: LRISK
Observations: 409

Variable	β	S.E.	t-stat.	Probability	VIF
C	-1.018	0.034	-29.566	0.0000	-
LEV	0.365	0.085	4.293	0.0000	1.059
ROA	-0.983	0.129	-7.604	0.0000	1.055
HSD	-0.397	0.065	-6.128	0.0000	1.059
LSD	0.116	0.034	3.420	0.0007	1.051
R^2	0.285			SS_{RES}	43.118
R^2_{ADJ}	0.278			F-stat.	40.344
S.E.	0.327			Prob. (F-stat.)	0.000

Table 20 Risk alternative dummy model – Regression results.

The model does not have a very high R^2 value, a common phenomenon in econometric regressions. Consequently, it can be concluded that the model has a satisfactory fitting and that the three independent variables provide a sufficient estimation for the firm's risk. At the same time, the adjusted R^2 does not deviate from the R^2, signifying that there is no spurious increase of the R^2 due to the inclusion of redundant variables. This conclusion is supported by the t-statistic and the respective probabilities, which are below the 5% threshold, suggesting that all variables are statistically significant at the 5% confidence level. As far as multicollinearity is concerned, the Variance Inflation Factors (VIF) are below the usual thresholds of 5 and 10, verifying that the model does not suffer from multicollinearity.

Once the model's fitting, significance, and multicollinearity are assessed, the coefficients must be analyzed and discussed as they are the ones that quantify the relationships among the regressors and the dependent variable. Both the ROA and HSD variables appear to negatively affect the firm's risk as their βs have negative signs, while the LEV and LSD have positive coefficients and, consequently, positive impact on the risk. Focusing on the impact of the ESG dummies, the following cases are examined:

Achieving an over 75% score in at least two of the ESG subcategories and, assuming that all other variables remain constant and that LRISK' is the new logarithmic market value:

$$\mathrm{LRISK} = z = c + \beta_1 \cdot \mathrm{LEV} + \beta_2 \cdot \mathrm{ROA} + \beta_3 \cdot 0 + \beta_4 \cdot \mathrm{LSD}$$

$$\mathrm{LRISK}' = z' = c + \beta_1 \cdot \mathrm{LEV} + \beta_2 \cdot \mathrm{ROA} + \beta_3 \cdot 1 + \beta_4 \cdot \mathrm{LSD}$$

The change in the risk can be expressed as:

$$\delta\mathrm{RISK} = \frac{e^{z'} - e^{z}}{e^{z}} = \frac{e^{z'}}{e^{z}} - 1 = e^{\beta_3} - 1 = e^{-0.397} - 1 = -33\%$$

On the other hand, if the scores fall below 25% score in at least two of the ESG subcategories, then, assuming that all other variables remain constant and that LRISK' is the new logarithmic market value:

$$\mathrm{LRISK} = z = c + \beta_1 \cdot \mathrm{LEV} + \beta_2 \cdot \mathrm{ROA} + \beta_3 \cdot \mathrm{HSD} + \beta_4 \cdot 0$$

$$\mathrm{LRISK}' = z' = c + \beta_1 \cdot \mathrm{LEV} + \beta_2 \cdot \mathrm{ROA} + \beta_3 \cdot \mathrm{HSD} + \beta_4 \cdot 1$$

The change in the risk can be expressed as:

$$\delta\text{RISK} = \frac{e^{z'} - e^{z}}{e^{z}} = \frac{e^{z'}}{e^{z}} - 1 = e^{\beta_4} - 1 = e^{0.116} - 1 = 12\%$$

The results can be interpreted as follows. A company that succeeds in increasing its ESG scores above 75% in at least two sub-categories, while maintain constant ROA and leverage, can reduce its annual risk by 33%. On the other hand, if it fails to meet high, or even mediocre, ESG standards, that could increase its annual risk by 12%. The current findings support the hypothesis that modern investors significantly value a firm's ESG performance.

Residual diagnostics

The residuals of the regression model should be tested for normality and homoskedasticity to assess the unbiasedness, consistency, and efficiency of the OLS estimators. The descriptive statistics of the residuals are presented in Table 21.

Mean	0.000
Median	0.003
Standard deviation	0.325
Minimum	-0.903
Maximum	1.132
Skewness	-0.131
Kurtosis	3.450

Table 21 Risk alternative dummy model – Residual diagnostics.

The Jarque-Bera test assesses the normality of the residuals. The null and alternative hypotheses are stated:

- H_0: The residuals are normally distributed.
- H_a: The residuals are not normally distributed.

The Jarque-Bera statistic follows a chi-square distribution with 2 degrees of freedom. At the 5% significance level:

$$\chi^2_{(2)\text{crit}} = 5.99 > 4.62 = \text{JB}$$

Therefore, the null hypothesis is accepted (fail to reject), and the distribution of the error terms is normal. A histogram of the residuals and a normal distribution curve are presented in Figure 19. It can be observed that the normal curve fits the histogram sufficiently, despite the slightly negative skewness depicted by the longer and flatter left tail of the histogram, and the slightly positive excess kurtosis, depicted by the slightly leptokurtic shape of the histogram.

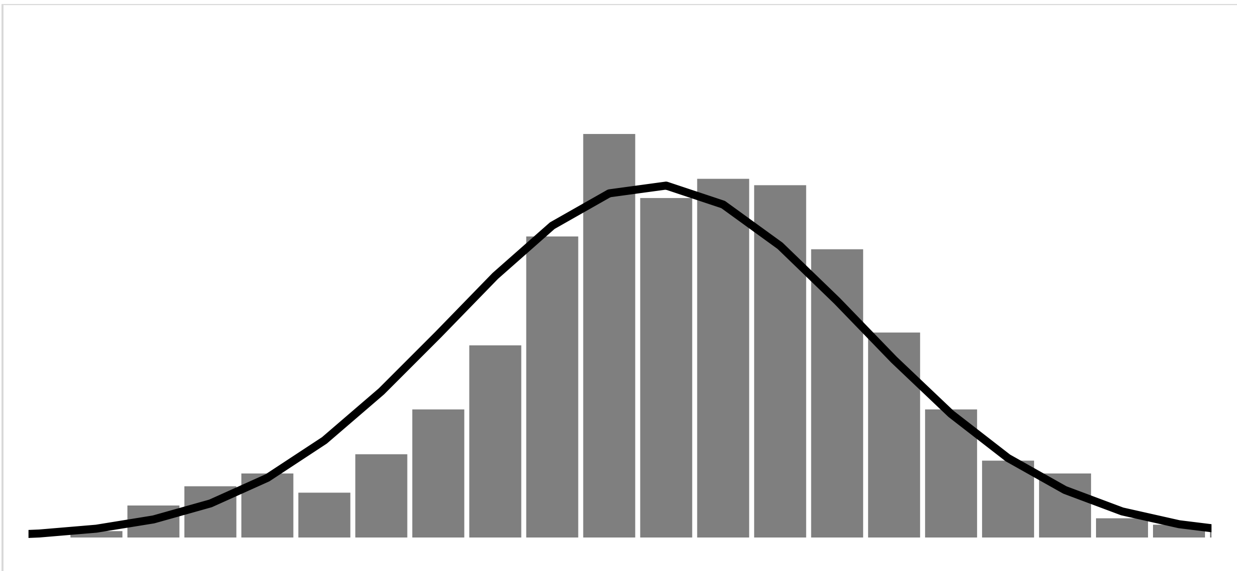


Figure 19 Risk alternative dummy model - Histogram of the residuals on a normal distribution curve.

The presence of heteroskedasticity is assessed by the White test. Initially, the squared residuals are regressed over the independent variables, their square values as well as their cross-products. The results of the regression are summarized in Table 22.

Dependent variable: ε^2
Observations: 409

Variable	β	S.E.	t-stat.	Probability
C	0.068	0.028	2.450	0.0147
LEV	0.106	0.112	0.941	0.3472
ROA	-0.067	0.133	-0.504	0.6146
LEV^2	0.092	0.131	0.705	0.4810
ROA^2	0.347	0.234	1.482	0.1392
HSD^2	0.038	0.074	0.514	0.6075
LSD^2	0.000	0.034	-0.009	0.9929
LEV·ROA	0.472	0.279	1.690	0.0918
LEV·HSD	-0.225	0.259	-0.868	0.3857
LEV·LSD	-0.067	0.096	-0.699	0.4852
ROA·HSD	0.261	0.371	0.704	0.4820
ROA·LSD	0.009	0.138	0.064	0.9489
R^2	0.035	SS_{RES}		10.749
R^2_{ADJ}	0.008	F-stat.		1305
S.E.	0.165	Prob. (F-stat.)		0.219

Table 22 Risk alternative dummy model – White test results.

The null and alternative hypotheses are stated:

- H_0: $\beta_1 = \beta_2 = \cdots = \beta_9 = 0$ (homoskedasticity).
- H_a: At least one $\beta \neq 0$ (heteroskedasticity).

The auxiliary regression has 11 degrees of freedom, therefore $n \cdot R^2 \sim \chi^2_{(9)}$. At the 5% significance level:

$$\chi^2_{(11)crit} = 19.68 > 14.27 = n \cdot R^2$$

Therefore, the null hypothesis is accepted (fail to reject), and the residuals of the model do not suffer from heteroskedasticity.

Forecast

The statistics employed for evaluating the forecast are presented in Table 23.

MAE	RMAE	MSE	RMSE
0.530	0.728	0.365	0.605
Theil's U	Bias	Variance	Covariance
0.383	0.758	0.105	0.137

Table 23 Risk alternative dummy model – Forecast results.

The model's results are similar to those examined in the original model. The model has a mediocre forecasting ability as Theil's U is slightly lower than 0.5. The high bias proportion also verifies the reduced forecasting performance of the model. However, the variance and covariance proportions are significantly lower, suggesting that no model revision is necessary.

4. Conclusions

The main conclusion of the thesis is that ESG metrics are already in place and widely acknowledged. Reporting on the company's ESG criteria and scoring high on ESG metrics has been proved to impact the company's value and risks.

Global and local guidelines and frameworks focusing on ESG and Sustainability are already in place. Even though there are opportunities for improvement, clear goals and implementation strategies have already been defined, and governments, communities, companies, and individuals are working towards achieving them. Methodologies for assessing the ESG scores, such as GRI, SASB, CSA, GHG Protocol, ATHEX, and Refinitv, have been identified and companies employ them to publicly report on their performance in terms of ESG. Based on the frameworks, the guidelines, and the tools analyzed, a due diligence checklist has been introduced for companies in the Energy Sector. The checklist consists of 26 controls points, divided into environmental, social, and governance practices. Based on the checklist, the reviewer can assess the company's performance on the ESG metrics and identify risks and opportunities.

The regression analysis confirms the rationale that the ESG is an intangible factor that significantly impacts the market value and risk of the energy firms. More specifically, the market value model reveals that a 1-unit increase in the overall ESG score leads to a 1.73% increase in the company's market value. This increase corresponds to $35.3m for an averagely-valued US energy company. Moreover, the alternative dummy model shows that very high (low) scores in the ESG subcategories result in a significant increase (decrease) of the firm's market value, suggesting that by improving (deteriorating) its ESG performance, a company can experience important growth (decline) in terms of market value. As far as the risk is concerned, the corresponding model proposes that a 10% increase in the overall ESG score leads to a 5.99% reduction in the annual risk faced by the energy firms. This reduction corresponds to a 2.93 percentage unit decrease for a firm of average risk. The alternative dummy model concludes that very high (low) scores in the ESG subcategories result in an important decrease (increase) of the firm's risk, suggesting that by improving (deteriorating) its ESG performance, a company can experience a substantial decline (growth) in terms of risk. Overall, the market value model is more robust as it has a higher R^2 and better forecasting performance. Despite this slight discrepancy, both models suggest that by focusing on its ESG performance, an energy firm can benefit by increasing its market value and reducing its annual risk.

In conclusion, investors and stakeholders must focus on the ESG as a factor that impacts the value of a company that will keep growing due to the purchasing behavior of the younger generations.

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