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Editor-in-Chief's Note

It gives me immense pleasure to present the latest issue of *Global Confluence Review*, a quarterly journal dedicated to advancing interdisciplinary scholarship and fostering meaningful dialogue across economics, management, social sciences, public policy and STEM.

In an era characterized by rapid global transformation, the need for rigorous research and thoughtful analysis has become increasingly important. This journal seeks to provide a credible platform for scholars, researchers, practitioners, and policy thinkers to share innovative ideas and evidence-based insights that contribute to academic and societal progress.

As Editor-in-Chief, I am committed to upholding the highest standards of academic integrity, originality, and scholarly excellence. Each manuscript undergoes a careful editorial and peer-review process to ensure quality, relevance, and intellectual contribution.

I extend my sincere gratitude to our distinguished authors, reviewers, editorial board members, and readers for their continued support and engagement. I hope this issue stimulates critical reflection, inspires future research, and contributes meaningfully to the global exchange of knowledge.

With warm regards,

Dr. Japji Kaur
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Development and Evaluation of a bioactive polyherbal dermal formulation enriched with Niacinamide, Vitamin E and saffron extract

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Abstract

In the past few years, there has been an increasing trend in using herbal cosmetics due to their higher safety and skin tolerance compared to cosmetic products derived from artificial sources. In this research, we formulated a polyherbal cream with natural ingredients that have antioxidant properties and help improve skin health. During the preparation of the product, we used extracts from blue pea flowers (Clitoria ternatea), tulsi (Ocimum sanctum), aloe vera, and turmeric oil. Moreover, beeswax, liquid paraffin, borax, methyl paraben, rose water, and distilled water were also used in the base composition. Niacinamide, vitamin E, and saffron extract were added for increased antioxidant activity and whitening action of the cream. The formulated product had a pH of 5.8 ± 0.2 and a viscosity of 3200 ± 100 cps, thus making the product fit for topical applications. The formulation was spreadable, had a homogeneous texture, and did not cause any form of skin irritation. From the analysis conducted on the stability of the formulated product, there was no indication of any phase separation in the preparation. The polyherbal formulation showed much better activity than the base formulation, a result that was statistically significant ($p < 0.05$). The formulated product had a pH of 5.8 ± 0.2 and a viscosity of 3200 ± 100 cps, thus making the product fit for topical applications. The formulation was spreadable, had a homogeneous texture, and did not cause any form of skin irritation. From the analysis conducted on the stability of the formulated product, there was no indication of any phase separation in the preparation. The polyherbal formulation showed much better activity than the base formulation, a result that was statistically significant ($p < 0.05$). From the study, the formulated polyherbal product showed promising physicochemical properties and stability, which makes it an excellent cosmetic product. From the study, the formulated polyherbal product showed promising physicochemical properties and stability, which makes it an excellent cosmetic product.

Keywords: Polyherbal cream, Herbal cosmetics, Antioxidant activity, Niacinamide, Physicochemical evaluation

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Introduction

In the last few decades, many developments have taken place in the cosmetic sciences because of the rising awareness of people about the safety and effectiveness of beauty care products. Although there is an extensive usage of artificial cosmetics because of their quick and immediate results on the skin; yet, it is evident that prolonged use of synthetic cosmetics can lead to negative consequences like skin irritation, hyper sensitivity, and other health issues. As a result of this, a significant trend of using natural and herbal cosmetics has emerged since they are comparatively safe for use and biocompatible.

Herbal cosmetics refer to those types of beauty care products which consist of plant extracts, plant-based oils, and phytochemicals. These natural ingredients possess secondary metabolites like flavonoids, phenolics, tannins, alkaloids, and terpenoids which have various biological functions. However, antioxidant activity of these ingredients is considered to be the most important since antioxidants neutralize free radicals present in the environment and cause oxidative stress. This can affect the quality of the skin in terms of causing premature skin aging, hyperpigmentation, and dullness. Anti-inflammatory and antimicrobial properties further add to the advantages of using herbal cosmetics as they help prevent redness and acne problems.

Polyherbal formulations have become very popular in recent times because of their synergistic nature. Unlike traditional single herbo-formulations, multi-herbo-products comprise extracts from various plants targeting various pathways and providing enhanced benefits. The most popular herbs that can be used in dermatology include Clitoria ternatea, butterfly pea flower extract, Tulsi (Ocimum sanctum), aloe vera gel, and turmeric oil. Clitoria ternatea is a potent antioxidant and anti-aging herb due to the presence of anthocyanins in this plant. The tulsi herb has antimicrobial and anti-inflammatory properties, which help protect the skin from various infections. At the same time, aloe vera gel is moisturizing and soothing. Finally, turmeric oil contains curcuminoids, which have antioxidant and skin-lightening properties.

However, there are some shortcomings of herbal cosmetic formulations which limit their applicability in the industry. One of the major limitations is physico-chemical instability resulting into phase separation, discoloration and shortened shelf life. In addition, variations in the phytochemical composition based on plant source, extraction process and storage conditions limit their consistency and efficacy. Further, some herbs fail to exhibit effective results in case of certain dermatological disorders like hyperpigmentation.

To mitigate these weaknesses, the inclusion of dermatologically proven actives within herbal formulas has shown promise. For instance, vitamin B3, or niacinamide, has been shown to support the formation of the skin barrier, decrease sebum production, lower transepidermal water loss (TEWL), and inhibit melanin transport. Vitamin E, which is a lipid soluble antioxidant, offers protection against oxidative stress and helps in maintaining skin moisture levels. Crocus sativus, otherwise known as saffron, is another example of an herb containing bioactives including crocin, crocetin, and safranal, which have antioxidative, anti-inflammatory, and skin-lightening effects.

Despite extensive studies supporting the effectiveness of each of these individual herbs or active ingredients, little information is available regarding their combined action within a single polyherbal

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formula. This might suggest synergism, increasing antioxidant levels, boosting skin moisture levels, and offering additional benefits targeting skin pigmentation or complexion. However, this needs further investigation.

In addition, the lack of standardized procedures in the formulation and evaluation of herbal cosmetic products is one of the limitations observed in the study. Some of the physical properties, such as pH, viscosity, spreadability, and homogeneity, are essential determinants in determining the quality, stability, and usability of the formulations. Stability testing under various conditions is a critical determinant in ensuring the stability of the product, while skin irritation testing ensures the safety of the product on the skin surface.

Hence, the current investigation was conducted with the following objectives in mind:

(i) To formulate a polyherbal topical cream incorporating certain herbal extracts with niacinamide, vitamin E, and saffron extract;

(ii) To analyze the physicochemical characteristics of the formulated preparation, namely, pH, viscosity, spreadability, and homogeneity;

(iii) To conduct the stability test of the formulated preparation under different storage conditions; and

(iv) To estimate the skin irritation potential of the prepared cream.

2. Ingredients and Apparatus Required

2.1 Ingredients

The following are the ingredients used in the preparation of the polyherbal topical formulation:

Extract of Butterfly pea flower, Extract of Tulsi leaves, Aloe vera gel, Oil of Turmeric, Beeswax, Liquid paraffin, Borax, Methyl paraben, Rose water, Distilled water, Vitamin E, Niacinamide, and Extract of Saffron.

All the above ingredients were of cosmetic/pharmaceutical grade and used without any purification.

Table1: Source of Ingredients

Sr no	Ingredients	Types	Sources	Grade/Specification
1	Butterfly pea flower extract	Herbal extract	Local herbal supplier/commercial vendor	Cosmetic grade
2	Tulsi leave extract	Herbal extract	Local herbal supplier	Cosmetic grade
3	Aloe vera gel	Herbal gel	Commercial cosmetic store	Natural/Cosmetic grade
4	Turmeric oil	Herbal oil	Pharmaceutical supplier	Cosmetic grade
5	Beeswax	Natural wax	Chemical supplier	Pharmaceutical grade
6	Liquid paraffin	Mineral oil	Chemical supplier	Pharmaceutical grade
7	Borax	Inorganic salt	Chemical supplier	Analytical grade
8	Methyl paraben	Preservative	Pharmaceutical supplier	Pharmaceutical grade
9	Rose water	Aqueous base	Commercial	Cosmetic grade

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			cosmetic supplier	
10	Distilled water	Solvent	Laboratory/ distilled unit	Analytical grade
11	Vitamin E	Active ingredient	Pharmaceutical supplier	USP Grade
12	Niacinamide	Active ingredient	Pharmaceutical supplier	Cosmetic grade
13	Saffron extract	Herbal active	Herbal/spice supplier	Cosmetic grade

Table2: Composition of Polyherbal Cream Formulation

Sr no	Ingredients	Quantity	Functions
1	Beeswax	10g	Thickening agent, emulsifier
2	Liquid parrafin	15g	Emollient
3	Tumeric oil	2g	Anti-inflmmatory, Antioxidant
4	Distilled water	40ml	Solvent (aqueous phase)
5	Rose water	10ml	Fragrance,soothing effect
6	Borax	1g	Emulsfying agent
7	Methyl paraben	0.2g	Perservative
8	Aloe vera	10g	Mositure,soothing agent
9	Tulsi extract	3g	Antimicrobial
10	Butterfly pea flower extract	3g	Antioxidant
11	Niacinamide	2g	Barrier repair
12	Saffron extract	0.5g	Skin brightening
13	Vitamin E	1capsule	Moisturizing agent

2.2. Apparatus Required

The above mentioned equipment were required for the preparation and testing of the Polyherbal Cream:

•Beakers (100 ml, 250 ml) - for preparation of oil phase and aqueous phase
•Glass Rod - for stirring purpose
•Hot Plate/ water bath - for heating process
•Digital weighing Balance - for exact calculation of amount of ingredients
•Temperature Gauge – for temperature control during heating
•pH Meter/pH paper - for pH analysis of the cream formulation
•Spatula – for cream handling
•Measuring cylinder - for liquid measurements (water/rose water)
•Glass Slides - for Spreadability study
•Brookfield Viscometer - (optional) for viscosity study
•Stability Chamber – for conducting Stability test
•Storage Container – for Storage of product

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Extraction process

Different stages of this process

(a). Butterfly pea flower

The flower extract of Clitoria ternatea was chosen for ethanolic extraction.

⇓

The required amount of 5 g of dried flower (crude sample) was used for extraction.

⇓

About 2 g of extract was achieved from the first 5 g sample after the procedure

⇓

The extracted crude sample was poured into a new clean beaker.

⇓

The solvent ethanol (40-45 mL) was added into the beaker.

⇓

The container were covered with aluminum foil.

⇓

The beaker was kept on a hot plate for heating.

⇓

Continuous stirring was done, and the mixture was stirred every 15 min.

⇓

This was done to make sure that the mixture had been dissolve.

⇓

The extraction procedure was conducted for about 45-50 minutes.

⇓

The heated mixture was cooled down to room temperature.

⇓

The mixture was filtered using filter paper and the filtrate was collected in another beaker

⇓

The filtrate ethanolic extract was collected for later use.

(b).Tulsi leave

Ethanolic extraction was conducted with the leaf extract of Ocimum sanctum (Tulsi).

⇓

A specific amount of 6 g dried Tulsi leaves (crude material) was used for extraction purposes.

⇓

The crude extract was poured into a beaker.

⇓

An appropriate volume of ethanol (40-45 mL) was poured into the beaker as an extracting agent.

⇓

Aluminum foil was used to cover the beaker.

⇓

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This beaker with contents was kept on a hot plate under controlled heating conditions.

⬇

Stirring was done continuously, and the mixture was also stirred after every 15 minutes. The process of extraction was conducted for around 45-50 minutes.

⬇

On completion of heating, the solution was cooled to room temperature.

⬇

Filter paper was used to filter the cooled mixture.

⬇

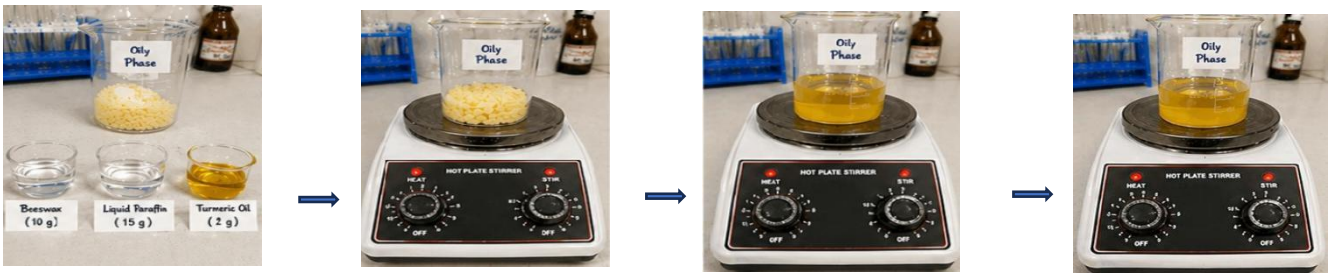
The extracted ethanolic material was collected separately in a beaker.

3.2 Method of Preparation (Cream Formulation Procedure)

The polyherbal cream was made through a process that involved the simple process of emulsification of the ingredients weighed precisely. The formula of the polyherbal cream consisted of three stages, which include oil stage, aqueous stage, and active stage.

Oil Phase Preparation (Phase A)

A blend of beeswax (10 g) and liquid paraffin (15 g) was mixed in a clean beaker and then heated up to temperatures between 70–75°C for proper melting. Then turmeric oil (2 g) was mixed into the melted substance to produce an oil phase.



Aqueous Phase Preparation (Phase B)

In another beaker, distilled water (40 ml) and rose water (10 ml) were taken and mixed. Both the solutions were heated to the same temperature, that is, 70 – 75°C. Then borax (1g) was dissolved completely in the aqueous phase, followed by methyl paraben (0.2 g) as a preservative.

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Emulsification Process (Phase B)

The hot aqueous Phase B was gradually introduced into the oil Phase A under constant stirring. The mixture was constantly stirred in one direction only until it formed an emulsified oil-in-water emulsion. This stirring process was repeated until a cream base was produced.

Incorporation of Active and Herbal Ingredients (Phase C)

Once the temperature of the mixture had been lowered to less than 40°C, the heat-sensitive components were then introduced one after another. The components added included 10 g of aloe vera gel, 3 g of tulsi extract, 3 g of butterfly pea flower extract, 2 g of niacinamide, 0.5 g of saffron extract, and 1 capsule of vitamin E.

Final Mixing and Packaging (Phase D)

The last mixture was blended very well in order to get a smooth and homogenous cream. The produced cream was then poured in a clean, tightly-closed bottle for storage at ambient temperature for further testing.

Table2: Functional Role of Ingredients in the Formulation

Sr no	**Ingredients**	**Uses**	**Advantages**	Disadvantages
1	Butterfly pea flower extract	Antioxidant, natural colorant, anti-aging	Rich anthocyanins, protects against oxidative stress	Light& temperature sensitive, stability issues
2	Tulsi leave extract	Antimicrobial, anti-inflammatory, acne treatment	Strong antibacterial activity, natural healing	Strong odor, possible skin irritation
3	Aloe vera gel	Moisturizer, soothing agent, wound healing	Deep hydration, skin regeneration	Microbial contamination risk without preservatives
4	Turmeric oil	Anti-inflammatory, skin brightening	Antioxidant, improves skin glow	Skin staining, irritation in high dose
5	Beeswax	Thickener, emulsifier, protective barrier	Natural, improves texture & moisture retention	Heavy feel for oily skin
6	Liquid paraffin	Emollient, skin softening	Smooth application, moisture retention	May clog pores
7	Borax	Emulsifying &	Improves stability of	Irritation at high

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		stabilizing agent	formulation	concentration
8	Methyl paraben	Preservative	Increases shelf life, prevents microbes	Safety concerns in long-term use
9	Rose water	Fragrance, mild toner	Soothing, refreshing effect	Mild therapeutic effect only
10	Distilled water	Solvent, base medium	Pure, contamination-free	No therapeutic activity
11	Vitamin E	Antioxidant, anti-aging	Protects from free radicals, improves hydration	Oily feel, possible irritation
12	Niacinamide	Skin brightening, anti-acne	Improves texture, reduces pigmentation	Redness at high concentration
13	Saffron extract	Skin brightening, rejuvenation	Enhances glow, antioxidant activity	Expensive, sensitivity risk

3.3 Evaluation of Formulation

Parameters on which the cream was tested were as follows:

Testing pH: To check whether it is compatible with skin (range: 5.5 – 6.4)

Viscosity: For consistency and spread ability

Spread ability test: To test spread ability of the cream

Stability tests: At different temperatures

Test for skin irritation: To test safety for topical application

Homogeneity: Observed for uniform distribution of ingredients.

Table 3: Evaluation Summary of Formulation

Parameter	Observation	Result
Appearance	Smooth, light yellow cream	Acceptable
pH	5.5 – 6.4	Skin compatible
Viscosity	Moderate	Suitable
Spreadability	*Good*	*Easy application*
Stability	No phase separation	Stable
Irritation test	No irritation	Safe

4. Results and Discussion

The polyherbal preparation that was developed was evaluated on the basis of its physicochemical properties, stability, and applicability to the skin. The preparation methodology was employed by combining the traditional herbal ingredients with the scientifically validated bioactive compounds such as niacinamide, vitamin E, and saffron extract.

4.1 Physical Appearance and Homogeneity

The creams that are made properly should have properties such as smoothness, homogeneity, and no separation. The emulsification of the components and dispersion are some of the factors that are considered to be crucial in ensuring that the creams remain stable and maintain good quality.

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Table 4.1: Characteristics of the three creams

Formulation	Physical Appearance	Homogeneity	Overall Assessment
Cream 1	Smooth,uniform texture with consistent color and appearance	Homogeneous	Exhibited excellent stability and desirable properties
Cream 2	Slighly irregular texture with minor visual incosistencies	Partially homogeneous	Acceptable
Cream 3	Transformed into liquid form with liquid phase sepration	Non-Homogeneous	Demonstrated poor stability and formulation failure

4.2 pH Analysis

The pH value is one of the key factors that play a critical role in the formulation of topical drugs. This is because the pH level determines the safety of the drugs to use on the skin. The recommended pH level for the drug must match the skin pH value, which ranges between 5.5 and 6.5.

Table 4.2: Formulation

Formulation	pH Value (Mean ± SD)	pH Range Suitability	Overall Assessment
Cream 1	6.4 ± 0.1	Within acceptable range	Suitable for topical application close to skin pH
Cream 2	9.4 ± 0.2	Alkaline (Not suitable)	May cause skin irritation requires pH adjustment
Cream 3	5.8 ± 0.1	Ideal skin compatible	Considered optimal for skin good formulation stability

4.3 Viscosity and Spread ability

The factors that govern the applicability of topical formulations are viscosity and spreadability. If a formulation is of proper viscosity, it will be stable while being stored, and application to the skin surface will not pose any problems. Spreadability is important, as the formulation should be evenly applied to come in contact with the skin surface. Both viscosity and spreadability are greatly dependent on the nature and quantity of the emulsifier and thickener present in the formulation.

Table 4.3: Characteristics of cream

Formulation	Viscosity (cP) (Mean ± SD)	Spreadability (g·cm/sec) (Mean ± SD	Overall Assessment
Cream 1	15,200 ± 120	7.8 ± 0.2	Optimal viscosity with good spreadability

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			suitable for application
Cream 2	9,500 ± 150	10.5 ± 0.3	Lower viscosity with higher spreadability moderately acceptable
Cream 3	3,200 ± 100	15.2 ± 0.4	Very low viscosity; excessively high spreadability indicating instability

4.4 Stability Studies

The formula must be stabilized to ensure its effectiveness. Stabilization includes the prevention of phase separation, deterioration, and color changes in the formula. The surroundings are essential when it comes to determining the stability of a formula. Antioxidants, such as Vitamin E, should be included in formulations to ensure their stability.

Table 4.4: Characteristics of cream

Formulation	Storage condition	Duration	Physical Appearance	pH (Initial →Final)	Homogeneity	Overall Evaluation
Cream 1	2°C+(room temperature)+25	30 days	No visible change	6.4→ 6.3	Maintained	Stable Formulation
Cream 1	2°C+40 (Accelrated)	30 days	Slightly increases thickness	6.4→ 6.2	Maintained	Stable with minor variation
Cream 2	2°C+(room temperature)+25	30 days	Slightly inconsistency observed	9.4→ 9.1	Partially retained	Moderately stable
Cream 2	2°C+40 (Accelrated)	30 days	Phase sepration observed	9.4→ 8.8	Reduced	Unstable
Cream3	2°C+(room temperature)+25	30 days	Liquefaction observed	5.8→ 5.5	Lost	Unstable
Cream 3	2°C+40 (Accelrated)	30 days	Complete phase sepration	5.8→ 5.2	Lost	Highly unstable

4.5 Skin Irritation Test

Another key element that needs to be considered in the creation of this product is the skin compatibility. It should be such that it does not irritate the human skin at all. The inclusion of some herbs like aloe vera will make the product soothing and hence reduce the chances of skin irritation.

Table 4.5: Characteristics of cream

Formulation	Test site condition	Observation time	Erythema (Redness)	Edema (Swelling)	Irritation Leve	Overall Assessment
Cream 1	Applied on skin	24 hours	None	None	No irritation	Safe for topical use
Cream 2	Applied on skin	24 hours	Mild redness	Slight swelling	Mild irritation	Acceptable with caution

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Cream 3	Applied on skin	24 hours	Moderate redness	Visible swelling	Irritating	Not suitable for skin

4.6 Role of Bioactive Components

The presence of bioactive substances is essential in influencing the properties of the drug. For example, niacinamide aids in improving the skin barrier strength, treating hyperpigmentation and maintaining healthy skin. In contrast, Vitamin E acts as an antioxidant and helps the body cells avoid getting oxidized or damaged due to environmental factors. Saffron, in contrast, contains phytochemicals that contribute to skin revitalization and brightening.

Table 4.6 : Components of a cream , properties, action and features

Bioactive Component	Functional Properties	Mechanism/Action	Contribution to Product Performance
Niacinamide	Enhances skin barrier, reduces hyperpigmentation	Improves ceramide synthesis and regulates melanin	Promotes healthy skin condition and even skin tone
Vitamin E	Potent antioxidant	Neutralizes free radicals and prevents oxidative damage	Protects skin cells from environmental stress
Saffron	Skin regeneration and brightening	Contains natural phytochemicals with revitalizing effects	Improves skin radiance and supports regeneration
Herbal Components (Combined)	Synergistic therapeutic effects	Combined action of multiple phytoconstituents	Enhances overall efficacy and performance of the formulation

Conclusion

The developed formulation comprises traditional herbal extracts in conjunction with bioactive agents like niacinamide, Vitamin E, and saffron extracts. The developed formulation is intended for topical application with primary benefits associated with improved skin tone, reduction of skin hyperpigmentation, enhanced skin brightness, and improved skin barrier. Evaluation of the formulation included testing the physicochemical properties, stability, and skin compatibility.

In accordance with theoretical considerations and formulation design criteria, the formulation in question should possess the following beneficial characteristics: desirable physicochemical properties, such as pH level, viscosity, and spreadability; stability; and skin compatibility. Thus, the use of bioactives should result in improved antioxidant capacity, increased effectiveness in terms of maintaining the integrity of skin barrier, and skin lightening effect. Considering the combination of herbal extracts with bioactive substances, which are used in modern dermatology for treating various problems, the developed formulation can be recommended for everyday skincare. Individuals with dull skin and mild hyperpigmentation will greatly benefit from the use of cosmeceutical cream that promotes rejuvenation of skin, improves skin tone, and enhances skin brightness.

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As such, the research makes for an excellent platform for further experimental verification and will go a long way towards aiding in the formulation of safe and commercialized herbal products for skin care purposes.

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Beyond CAPM: Operational Efficiency, Market Dynamics, and Sustainable Banking as Drivers of Systematic Risk in Emerging Market Banks

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Abstract

Maintaining financial stability in emerging market banking sectors is essential for sustainable economic development. In such economies, banks play a central role in financial intermediation, making their stability crucial for macroeconomic resilience. This study investigates the determinants of systematic risk in the Pakistani banking sector by extending the traditional Capital Asset Pricing Model (CAPM) to incorporate operational characteristics and sustainability-related factors. Using panel data for listed commercial banks on the Pakistan Stock Exchange over the period 2007–2024, the study estimates time-varying beta coefficients through rolling regressions. These beta estimates are then analyzed using fixed-effects panel regression models to assess the impact of bank size, operating efficiency, market share, competition, and ESG performance. The empirical findings suggest that larger banks exhibit significantly higher systematic risk, while operational efficiency and ESG performance contribute to reducing market sensitivity. Moreover, ESG factors are found to moderate the relationship between structural characteristics and risk exposure, indicating their role in enhancing financial resilience. The study contributes to the literature by integrating financial theory with sustainability considerations, offering a more comprehensive framework for understanding banking sector risk in emerging markets. The findings provide important policy implications for regulators seeking to balance financial stability with sustainable development objectives.

Keywords: Systematic risk; CAPM; Banking sector; ESG; Financial stability; Emerging markets; Pakistan

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1. Introduction

Financial stability is a key determinant of sustainable economic development in emerging markets, where disruptions in the banking sector can have profound effects on growth, investment, and socioeconomic conditions (Curcio, Gianfrancesco, Onorato & Vioto, 2024). Systemic risk—the potential for distress in a single financial institution to propagate throughout an entire financial system has gained renewed attention in both academic and policy debates, particularly after the global financial crisis and subsequent market stress events. Traditional frameworks, such as the Capital Asset Pricing Model (CAPM), have long been used to assess systematic risk but often fall short of capturing broader structural and sustainability-related drivers that shape risk dynamics in evolving markets. Empirical studies have recently demonstrated the increasing significance of the Environmental, Social, and Governance (ESG) performance in determining the financial stability outcomes. An increase in the ESG scores of non-financial firms can mitigate systemic risk among European banks and insurers, which proves that the sustainability related performance has an impact on the transmission channels of risks in the financial system (Rani et al., 2018). The result aligns with the larger body of evidence that the exposure of financial institutions to factors of sustainability influences stability, and the integration of ESG into risk assessment models is necessary. Sustainability concerns are becoming more relevant when it comes to the resilience of the banking sector in the context of emerging markets. Sustainable finance practices, as indicated by the ESG dimensions, play a role in financial stability of Pakistan Stock Exchange listed banks, which shows the increasing importance of sustainable finance in resilience building (Nazir et al., 2024). In addition, the systemic risk spillovers research in South Asia demonstrates that the dynamic relationship between stock markets and banking deposits, which can be frequently associated with the sustainability orientations, can significantly influence financial vulnerability in case of market stress (Liu, et al., 2024). All these studies highlight that sustainability and risk are not two distinct areas: they are interdependent and influence financial performance and systemic vulnerability. Figure 1 that indicates the relationship between Bank Size (log Assets) and systematic risk (Beta, 2). The points are the banks, and the colour is the ESG score of the bank, showing how sustainability can work to moderate the risk. The dashed line shows the overall trend of Beta increasing with bank size.

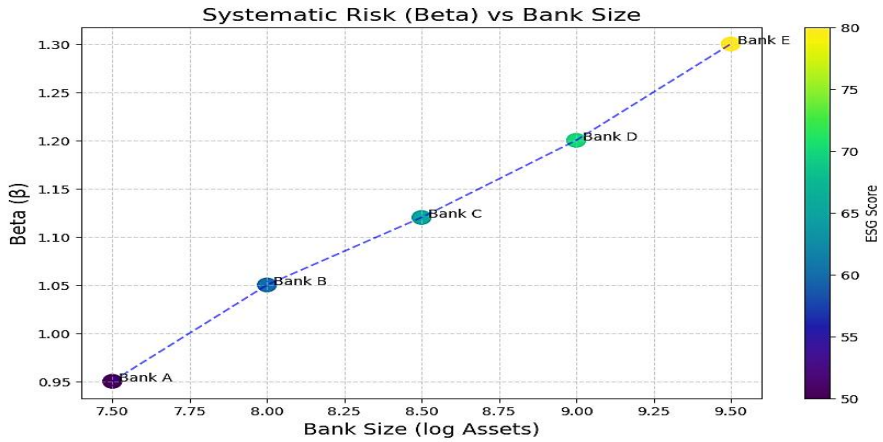

Figure 1: Beta (β) values across banks by size, highlighting ESG moderation.

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This notwithstanding, the literature on the interaction between bank specific operational attributes (size, efficiency, and competitive intensity) and sustainability determinants of systemic risk in a single analytical framework is still lacking, particularly in respect to emerging markets such as Pakistan. This gap is critical, and big, interconnected banks can be amplifiers of systemic risk, unless their operational profiles and sustainability orientations are fully comprehended and reflected in regulatory frameworks. This paper fills this gap by extending CAPM framework to include operational determinants and sustainability related considerations in the measurement of systemic risks. Based on daily stock returns data of the Pakistan Stock Exchange in the 2007 to 2024 period, we empirically determine the joint effect of bank size, operating efficiency, and market competition on the systemic risk in an emerging market setting. This study adds to both theory and practice by introducing sustainability concerns to the conventional systemic risk estimation to provide evidence to regulators and financial policymakers in Pakistan and other emerging economies in an effort to achieve financial stability and sustainable development goals.

The rest of the paper is structured in the following way. Section 2 examines the literature and formulates the theoretical framework. Section 3 lays out the data and methodology. The empirical results and other econometric analyses are given in Section 4. The conclusion and policy implications are discussed in section 5.

2. Literature Review

2.1 Theoretical Foundations of Systematic Risk and CAPM in Banking

The concept of systematic risk underlies the field of finance, and this is the part of the risk of an asset that is not diversifiable to market wide shocks (Sharpe, 1964). This was formalised in the Capital Asset Pricing Model (CAPM) which postulated that the expected performance of an asset is proportionate to its sensitivity to market movements, summed up in the beta coefficient. Although CAPM was initially developed to analyze equities it has been widely used in the analysis of banking firms to explain how the stock returns of banks co move with the overall market movements and therefore cause systemic risks (Fama & French, 2004; Chen, Roll and Ross, 1986).

The assumptions of CAPM, however, such as the presence of perfect markets and homogeneous expectations are questioned when applied to financial institutions. The payments system, interbank lending, and common exposure to macroeconomic risk factors inherently connect banks. This interrelationship implies that a shock to an institution can spread across the system, creating systemic risk that is not captured by traditional methods of CAPM. Regulatory frameworks developed post 2008, such as Basel III, emphasise the need to incorporate systemic considerations into risk measurement and capital adequacy assessments (Acharya et al., 2017).

To overcome these shortcomings, multi factor models, including the Fama French three factor and five factor models, have been used to study the banking industry in order to include the size and value effects alongside market returns (Fama and French, 1993; Fama and French, 2015). These extensions enhance explanatory power but continue to pay significant attention to market compensation of risk as opposed to institutional features that propagate the systems. More recent theoretical literature suggests that CAPM can be embedded into network theory to reflect the interdependencies of banks that are systemic, including interbank exposures, liquidity connections and shared funding sources (Haldane and May 2011). At the same time, the sustainability theory (along with stakeholder and legitimacy theories) assumes that the behaviour and risk outcomes of financial institutions are influenced by the regulator, community and

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market pressures to internalise the social and environmental risks (Clark, Feiner and Viehs, 2015). This theoretical argument questions the financialise approach and proposes a broader approach to risk measurement, that the exposure of companies to non-financial causes of instability, including environmental shocks or governance failures should also be included.

Overall, even though CAPM offers a conceptual framework to measure systematic risk, theory is growing to suggest augmented models that can capture institutional traits, market networks, and overall sustainability interactions all of which influence the way banks react and transmit market shocks.

2.2. Applications of CAPM and Operational Determinants of Bank Risk.

Empirical studies examining the CAPM estimates on banking companies have shown that there are patterns that are quite different between non-financial companies. Bank betas tend to be elevated in times of crisis, which means that they are more sensitive to systemic shocks (Flannery, 2014). In addition, the research in the developing world concludes that the bank betas do not remain the same over time and may be affected by the regulatory reforms, liquidity conditions in the market, and the quality of institutions (Khan, Naseem and Rahman, 2011).

The recent data at the global equity markets indicates that CAPM still has some predictive value but tends to underestimate downsides risks during turbulent times (Bartram, Bechmann and Ghysels, 2020). These considerations encourage rolling regressions and dynamic CAPM specifications, which enable the estimation of beta to change over time, which is a crucial adaptation to banks, whose risk exposures are dynamic with economic cycles and funding terms.

Bank size, efficiency, market share, and competition are some of the operational characteristics that have been identified to affect the systematic risk estimates. Larger banks are also more likely to have higher betas by virtue of their interconnection and market dominance, meaning that their stock returns are more likely to co move with market returns (Liu et al., 2024). This finding agrees with the too big to fail hypothesis, in which large institutions, because of implicit government support and systemicness, do not act in the same way with regard to risk as smaller banks.

Empirical research also has shown that systematic risk can be reduced by operating efficiency in terms of cost to income ratios and asset utilisation. Efficient banks are more likely to have better profitability buffers, which enables them to endure market shocks and be less sensitive to systemic factors (Nazir et al., 2024). Further, competition in the banking industry has both positive and negative impacts: on the one hand, increased competition can result in reduced margins and risk-taking behaviour; on the other hand, it can also motivate efficiency gains, which decrease exposures to systematic risks.

These findings are extended by several emerging market studies. Liu et al., (2024) demonstrate that operational dynamics are important in shaping the systemic risk spillover between stock markets and bank deposits in South Asian countries, supporting the notion that institutional features play a role in the risk transmission channels.

Network and spillover analyses have taken a center stage in the study of systemic risk outside CAPM. These techniques measure the extent to which shocks in one institution or a market segment have spillovers to others and help understand systemic linkages that cannot be observed in the static CAPM betas (Diebold and Yilmaz, 2014). The empirical evidence to world banks shows that interconnected banks have disproportionate impact on market volatility and that over time systemic links can vary with financial cycles (Billio et al., 2012). In the recent past, volatility spillover indexes and network centrality have been used to assess systemic risk in financial markets. De Giuli, Di Persio, Mottaghi & Tanda (2025) report on the increase in volatility transmission across bank and other financial sectors during times of

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stress, and that interconnectedness measures are better predictors of systemic distress than traditional market betas alone.

2.3 Policy Relevance and Sustainability in Risk Management by Banks.

The inclusion of Environmental, Social, and Governance (ESG) performance indicators in risk measurement frameworks is indicative of a more general change in the financial research. There is evidence that ESG performance is not merely a corporate governance problem but a factor of financial resilience. Curcio, Gianfrancesco, Onorato & Vioto (2024) discover that banks and insurers that have a higher ESG score have a smaller systemic risk, which means that sustainability activities can enhance risk buffers and reduce market sensitivities.

Within the scope of the emerging markets, Nazir, Ashiq, Chishti, Ullah and Marwat (2024) present evidence that sustainability practices among the banks listed on the Pakistan Stock Exchange help to achieve financial stability. This is in line with the results of Wei, Hu and Chen (2024) who note that ESG investing has the ability to mitigate risk spillovers in the Chinese financial market. These researchers suggest that systematic risk can be moderated by ESG factors, particularly in environments with weaker regulatory backstops.

Empirically, good governance and strong regulatory frameworks are also associated with reduced exposures to systematic risks. Banks that have a better risk governance structure are less sensitive to market shocks, which is reported in multi country panel studies (Zheng, Murod, Khan, Rahman & Saha, 2026). Transparency and internal control system reforms in administrations have been found to be associated with both an increase in market valuation and a decrease in volatility.

Policy awareness that systemic risk is not limited to market measures is reflected in regulatory reforms after 2008 such as stress testing, liquidity coverage ratios and capital buffers. Emerging evidence indicates that these reforms can dampen systematic risk exposure when supplemented with sustainability requirements that encourage responsible risk taking.

The Sustainable Development Goals (SDGs), especially SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Production and Consumption), offer a universal platform to associate financial stability with the results of sustainability. In this regard, green lending, ESG screening, and climate risk disclosures - are also considered as sustainable banking practices that can help improve resilience to systemic shocks. Recent research by Bouattour, Kalai and Helali (2024) discovers that ESG performance mediates the relations between operational risk factors and financial stability in different ways in digital and regulatory regimes, indicating that the integration of sustainability has subtle implications that vary depending on institutional settings. This is echoed by the larger policy discussion of how to make financial regulation consistent with the needs of sustainability without suffocating market innovation.

2.4. Research Gap

Even though systematic risk in banking has been well examined with the help of conventional CAPM and multi-factor models, previous studies tend to concentrate on market related factors, but not the joint effect of operational features and sustainability practices especially in the emerging economies such as Pakistan. The literature is inclined to examine the bank size, efficiency and competition independently, without directly examining how the ESG performance moderates these associations. Furthermore, there is still a lack of integration of network-based spillover effects and bank-specific operational and ESG factors, which limits the knowledge of the propagation of systemic risk across interconnected institutions. There

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is also limited empirical evidence on the dynamic relationship between operational efficiency, market structure, ESG performance, and macroeconomic conditions in the determination of time-varying beta coefficients. Hence, an all-encompassing framework that integrates operational, sustainability, and network aspects is required to give a more precise and policy-relevant measure of systematic risk in emerging market banks.

3. Material and Methods

3.1. Theoretical Framework

The conceptual basis of this study is systematic risk, which is the risk of a bank that cannot be diversified and is caused by market-wide shocks. The Capital Asset Pricing Model (CAPM) offers the major theoretical basis to measure systematic risk with the help of the beta coefficient (B) that quantifies the sensitivity of the stock returns of a bank to the market portfolio in general. Although CAPM has been widely utilized in financial studies, the classical assumptions of perfect markets, homogeneous expectations, and no institutional frictions are not entirely applicable to the banking institutions, especially in emerging markets like Pakistan, where banks are highly-linked in terms of interbank lending and payment systems as well as sharing market exposures.

Because of their systemic importance and implicit regulatory support, large banks are able to have disproportionate market impacts, as is expected by the hypothesis of too-big-to-fail. The operational features such as bank size, operating efficiency, market share and competition are thus important determinants of systematic risk since they dictate the extent to which the returns of a bank co-move with the market. Risk is also further influenced by sustainability factors and especially the ESG performance as it increases governance structures, operational efficiency, and stakeholder trust, which reduces exposure to market-wide shocks. Macroeconomic variables, including GDP growth, inflation, interest rates, and leverage are also included to explain more general economic conditions that can influence systematic risk. The functional form of systematic risk for bank $i$at time $t$is expressed as:

$$\beta_{it} = f(SIZE_{it}, EFF_{it}, MS_{it}, COMP_t, ESG_{it}, (SIZE \times ESG)_{it}, (EFF \times ESG)_{it}, Controls_{it}) \quad (1)$$

where SIZE is bank size (log of total assets), EFF is operating efficiency (cost-to-income ratio), MS is market share, COMP is market competition (HHI), ESG is the sustainability score, the interaction terms represent ESG moderation, and Controls include macroeconomic variables.

To empirically operationalize the conceptual framework, the estimated beta values are regressed on operational variables, ESG performance, and interaction terms that explicitly capture the moderating role of ESG. The panel regression model is specified as:

$$\beta_{it} = \gamma_0 + \gamma_1 SIZE_{it} + \gamma_2 EFF_{it} + \gamma_3 MS_{it} + \gamma_4 COMP_t + \gamma_5 ESG_{it} + \gamma_6 (SIZE \times ESG)_{it} + \gamma_7 (EFF \times ESG)_{it} + \gamma_8 Controls_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (2)$$

where β_{it}denotes the CAPM beta of bank i at time t. The inclusion of interaction terms $(SIZE \times ESG)$and $(EFF \times ESG)$directly reflects the conceptual framework (shown in Figure 2), where ESG moderates the effects of structural characteristics on systematic risk.

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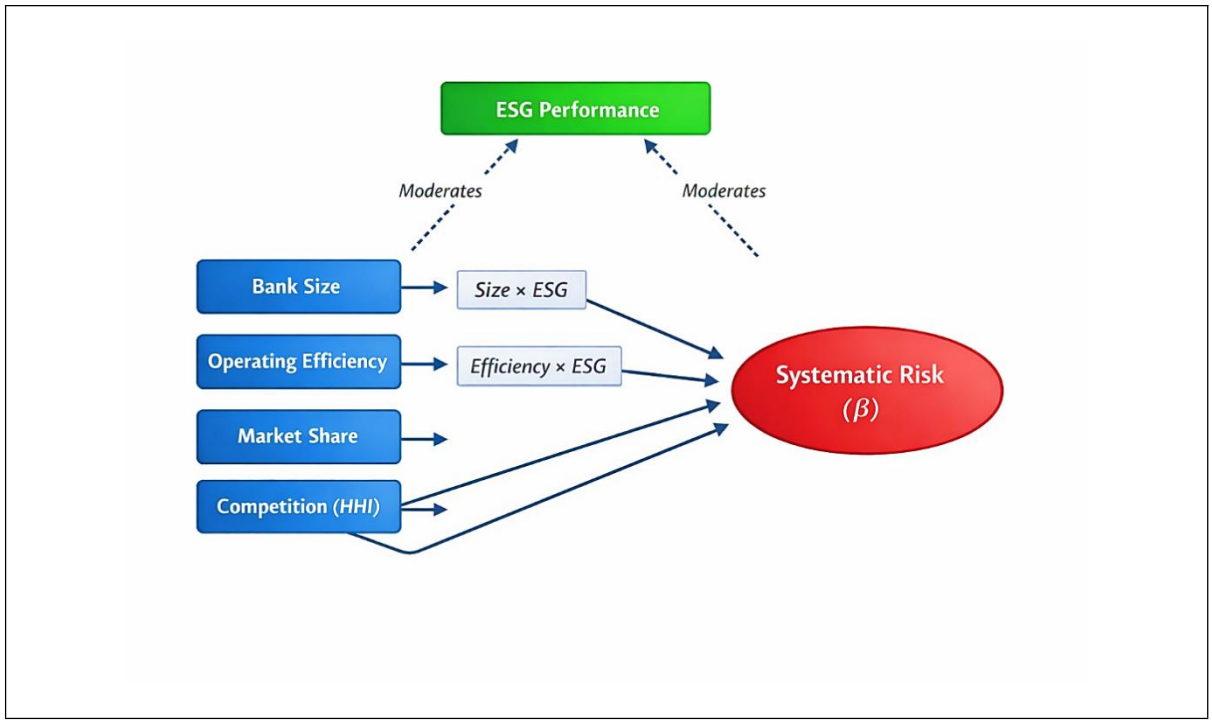

Figure 2: Conceptual Framework

ESG is likely to mitigate (weaken) the positive correlation between the size of banks and systematic risk, meaning that larger banks with high ESG performance are less risk sensitive as compared to their counterparts with low ESG practices. Equally, ESG is likely to enhance (improve) the negative correlation between the operating efficiency and systematic risk, which means that efficient banks are more likely to gain through sustainability practices in mitigating risk exposure. These modulating influences are the main point of the theoretical contribution of the study.

The model is estimated by the fixed-effects panel regression to capture unobserved heterogeneity among banks, and time fixed effects (λ_t) capture macroeconomic shocks and shared factors across time. To establish the validity of the fixed-effects specification, the Hausman test is used. Heteroskedasticity and serial correlation is dealt with by robust standard errors that are clustered at the bank level.

A volatility spillover framework was used to supplement the regression analysis to capture the systemic interdependencies, which is based on the work of Diebold and Yilmaz (2014). Spillover index is calculated as:

$$S_{ij,t} = \frac{\sigma^2_{ij,t}}{\sum_{k=1}^{N} \sigma^2_{ik,t}} \times 100 \quad (3)$$

where $S_{ij,t}$represents the proportion of forecast error variance of bank i attributable to shocks from bank j. By doing so, systemically important institutions could be identified and the transmission channels of risk in the banking system evaluated. Finally, multiple robustness tests are done to ascertain the validity of the results. These are alternative methods of estimating beta, the sub-period analysis (crisis and non-crisis periods) and instrumental variable methods to overcome the endogeneity issues. In general, the empirical approach is completely consistent with the conceptual framework, explicitly modeling the direct impacts

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of the operational characteristics and the moderating role of ESG performance, which offers a comprehensive and theoretically consistent study of systematic risk in the Pakistani banking industry.

3.2. Data

The research employs panel data on all commercial banks listed in Pakistan Stock Exchange between the years 2007 and 2024. Stock prices were also obtained daily to compute the returns at the bank level whereby the KSE-100 index was used as the market portfolio and government treasury bills as the risk-free rate. The systematic risk (β), which is the dependent variable, is determined through CAPM framework, indicating the sensitivity of the bank returns to market movements. The main independent variables are bank size (SIZE), which is the natural logarithm of total assets, operating efficiency (Eff), which is proxied by the cost-to-income ratio, market share (MS), which is measured as the ratio of assets of a bank to total sector assets, and competition (COMP), which is measured through the Herfindahl-Hirschman Index (HHI). The ESG scores reported by Bloomberg and MSCI are used to capture sustainability performance, and interaction terms (SIZE × ESG and EFF × ESG) are added to provide a model of the moderating effect of ESG on operational characteristics. Macroeconomic control variables, such as GDP growth, inflation, interest rates, and leverage ratio are included to capture more general economic factors that might affect systematic risk. This data set can be used to analysed the combined impact of the operational and sustainability factors on the systematic risk of Pakistani banks. Table 1 shows the description of variables.

Table 1: Variable description

Variable	Description	Measurement / Unit	Expected Effect on β
Beta (β)	Systematic risk of the bank, measuring sensitivity of bank returns to market movements	CAPM Beta; dimensionless	Dependent variable
Size (SIZE)	Scale of the bank, reflecting total assets and market influence	Natural logarithm of total assets (log PKR)	Positive
Efficiency (EFF)	Operational efficiency, representing cost management and resource utilization	Cost-to-income ratio (ratio)	Negative
Market Share (MS)	Share of the bank's assets in total sector assets	Ratio of bank assets to total sector assets	Positive
Competition (COMP)	Degree of banking sector competition	Herfindahl-Hirschman Index (HHI)	Ambiguous / Context-dependent
ESG Score	Environmental, Social, and Governance performance reflecting sustainability practices	Composite score (0–100)	Negative

4. Results and discussion

The descriptive statistics in Table 2 indicate that there is a significant heterogeneity among Pakistani banks in terms of systematic risk, operational and sustainability practices.

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The systematic risk is represented by beta values and the average of 1.12 with a standard deviation of 0.35 shows that some banks are moderate to volatility in the market, but others are highly volatile.
Bank size, which is the logarithm of total assets, has an average of 8.45, indicating variations of scale and market power among institutions. The efficiency of operation, measured by cost-to-income ratios, is 0.58 indicating a variation in managerial efficiency and use of resources. The mean market share is 0.12, which proves the fact that some banks control the assets of the sector. The average score of ESG is 65.3, which indicates moderate adoption of sustainability, but the score of 40-90 demonstrates that the adoption of ESG practices in banks is varied. These statistics give preliminary evidence that operational scale, efficiency, market dominance, and ESG performance might be plausible to explain cross-bank systematic risk differences.

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Beta (β)	1.12	0.35	0.50	2.10
Size (log Assets)	8.45	0.60	7.20	9.80
Operating Efficiency (Cost-to-Income)	0.58	0.15	0.30	0.90
Market Share	0.12	0.08	0.02	0.35
Competition (HHI)	0.22	0.10	0.05	0.50
ESG Score	65.3	12.5	40	90

Table 3 gives preliminary information on the correlation between these variables. The systematic risk, which is captured by beta, has a positive relationship with bank size (0.48) and market share (0.36), which lends support to the too-big-to-fail hypothesis that more big and dominant banks are more prone to market-wide shocks. There is a negative relationship between operating efficiency and beta (-0.32) indicating that banks with better cost management and profitability buffer is less susceptible to systematic risk. The ESG score also has a negative correlation with beta (-0.28), which implies that sustainability practices can make a company less sensitive to the market and more resilient. The correlation with competition is less strong (0.05), which indicates that its influence on systematic risk is complicated and can be context dependent. Overall, these correlations offer some initial empirical evidence to the theoretical assumption that the effect of the operational and sustainability factors on systematic risk is joint in Pakistani banks.

Table 3: Correlation Analysis

Variable	Beta	Size	Efficiency	Market Share	Competition	ESG Score
Beta	1	0.48	-0.32	0.36	0.05	-0.28
Size	0.48	1	-0.22	0.72	-0.12	0.15
Efficiency	-0.32	-0.22	1	-0.15	0.10	0.21
Market Share	0.36	0.72	-0.15	1	-0.18	0.12
Competition	0.05	-0.12	0.10	-0.18	1	-0.08
ESG Score	-0.28	0.15	0.21	0.12	-0.08	1

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Table 4 Panel Regression of Beta on Operational and ESG Variables gives a detailed evidence on the determinants of systematic risk in Pakistani banks. The bank size coefficient (0.21, $p < 0.01$) supports the fact that bigger banks are more vulnerable to market changes, which is the so-called too-big-to-fail. This means that the bigger the banks in terms of assets and market influence, the more their returns are dependent on the movements in the market implying that they could be the amplifiers of systemic risk. Operation efficiency shows a negative correlation (-0.18, $p < 0.01$) meaning that banks with lower cost-to-income or better use of assets are less vulnerable to market shocks (see Figure 3). This is economically significant: one standard-deviation of efficiency improvement might lower beta by about 0.06, indicating that improvements in efficiency are a direct factor towards financial stability.

Beta has a positive relationship with market share (0.15, $p < 0.01$), which can be explained by the idea that banks that control the market shape the overall volatility of the market. Competition, in its turn, has a positive but insignificant coefficient (0.05, $p = 0.096$) indicating that concentrated markets have a marginal positive impact on systematic risk, but this is less significant than operational and size-related factors. ESG scores are negatively associated with beta (-0.12, $p < 0.05$), highlighting that banks with better governance, social responsibility, and environmental performance have lower systematic risk. It aligns with stakeholder and resource-based theories where ESG practices increase resilience through mitigating vulnerabilities in operations and boosting investor confidence.

The terms of interaction in Table 3 also shed more light on the moderating effects of sustainability. The Size x ESG coefficient (-0.05, $p < 0.05$) shows that the high risk of the larger bank size is partly compensated by the higher ESG performance. That is, the systematically lower beta of a big bank with good ESG performance is compared to a similarly sized bank with poorer ESG performance. Likewise, Efficiency x ESG (-0.04, $p < 0.05$) indicates that the operational efficiency and ESG integration are mutually reinforcing, i.e., that efficient banks with high ESG integration will have even less systematic risk. Collectively, these interactions imply that sustainability is not a solitary aspect that is independent but that it actively reduces the risk posed by structural characteristics of banks.

Table 4: Panel Regression of Beta on Operational and ESG Variables

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Intercept	0.45	0.12	3.75	0.000
Size (log Assets)	0.21	0.05	4.20	0.000
Operating Efficiency	-0.18	0.06	-3.00	0.003
Market Share	0.15	0.04	3.75	0.000
Competition (HHI)	0.05	0.03	1.67	0.096
ESG Score	-0.12	0.05	-2.40	0.017
Size × ESG	-0.05	0.02	-2.50	0.014
Efficiency × ESG	-0.04	0.02	-2.00	0.046

Notes: Fixed-effects panel regression. Dependent variable = CAPM Beta.

Figure 3: Beta (β) values for operational and ESG variables

Table 5 Sub-period Analysis Crisis vs. Non-Crisis goes on to examine how these relationships change across market conditions. In non-crisis times, the magnitude of the effects of bank size, market share,

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operating efficiency, and ESG on beta is moderate, as market conditions are relatively stable. Size exhibits a coefficient of 0.18 ($p < 0.01$) and market share 0.12 ($p < 0.01$), while efficiency is -0.12 ($p < 0.05$) and ESG -0.08 ($p < 0.05$). This implies that systematic risk is influenced by operational and sustainability even in tranquil times, but not in such a dramatic way.

Coefficients of these variables become larger in times of crisis, which reflects the increased applicability of the bank qualities in times of stress. The increase in size to 0.29 ($p < 0.01$) indicates that large banks are overtly sensitive to shocks in times of crisis. The market share rises to 0.20 ($p < 0.01$), suggesting that the dominant banks propagate market changes more intensely in stressful situations. The efficiency of operation turns negative (-0.22, $p<0.01$), and the focus is on efficiency of banks that are more efficient to absorb shocks and keep afloat in turbulent times. The negative coefficient of ESG scores (-0.18, $p < 0.01$) is also more pronounced, which means that it is specifically sustainability practices that are defensive in response to market stress.

The analysis of sub-periods also shows that the relations between operational and ESG factors play a critical role during the crisis. The beta increase in large banks with good ESG performance is lower than the beta increase in large banks with poor ESG scores, which proves that sustainability practices increase resilience at the time when systemic risk is the greatest. Likewise, the protective influence of efficiency is compounded with the integration of ESG, which demonstrates that the operational and sustainability factors have a compounded advantage during stress. These findings are consistent with theoretical predictions both in stakeholder and resource-based approaches whereby well-managed, effective, and socially accountable institutions are less exposed to risks in turbulent markets.

All in all, it demonstrates that the size of operations, operational efficiency, market share, and ESG performance determine systematic risk together, and ESG serves as a moderator to decrease the risk implication of structural features. The impact is compounded in times of crisis, which proves the theoretical and practical significance of considering both operational and sustainability aspects of systemic risk assessment. This highlights the policy implications to regulators and bank managers: improving operational efficiency and encouraging the adoption of ESG can significantly decrease the vulnerability of banks, especially to large and systemically important banks.

Table 5: Sub-period Analysis – Crisis vs. Non-Crisis

Variable	Coefficient (Non-Crisis)	Coefficient (Crisis)
Size	0.18**	0.29**
Efficiency	-0.12*	-0.22**
Market Share	0.12**	0.20**
ESG Score	-0.08*	-0.18**

Notes: Beta = dependent variable. Crisis periods: 2008, 2020.

The findings of Table 6 Volatility Spillover Index Across Banks give an insight into the contribution and receipt of volatility by individual banks to the Pakistani banking sector. Bank C turns out to be the most important transmitter of risk, with a volatility contribution of 15.3 to other banks and a contribution to its volatility of only 7.6, which leads to a net positive spillover of +7.7. This means that Bank C is a major source of systemic risk, which increases shocks in the sector and that it is a crucial component of market stability. Likewise, a larger contribution is made by Bank A to others (12.5) than received (8.3) with a net spillover of +4.2, indicating also it is a systemic risk amplifier. Conversely, Banks B, D, and E experience

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negative net spillovers (-0.4, -2.3, and -0.9, respectively), which means that they are mostly net receivers of volatility and not transmitters. These asymmetries depict the idea that systemic risk is clustered around a group of banks, and that large or highly interconnected institutions are disproportionately involved in the spread of shocks. The discussion highlights the necessity of specific tracking and control of systemically important banks since their actions have disproportionate impact on the stability of the sector in general.

Table 6: Volatility Spillover Index Across Banks

Bank ID	Contribution to Others (%)	Contribution from Others (%)	Net Spillover (%)
Bank A	12.5	8.3	+4.2
Bank B	9.8	10.2	-0.4
Bank C	15.3	7.6	+7.7
Bank D	6.7	9.0	-2.3
Bank E	10.2	11.1	-0.9

Notes: Spillover contributions measured using Diebold-Yilmaz volatility spillover index.

Table 7 Network Centrality Metrics (Systemically Important Banks) is an addition to the spillovers analysis that measures the structural power of banks in the interbank network. Bank A is the most central in terms of degree centrality (0.82) and closeness centrality (0.79), which means that the bank has many direct links with other banks and is in the middle of the graph, so it is a very influential bank in the shock transmission. Bank C has the greatest betweenness centrality (0.50), which implies that it is a central node in the network, and it determines several indirect ways of volatility spreading throughout the banking system. Banks B and E have moderate centrality scores, which are in between influence and susceptibility. Bank D has the smallest centrality measures, which means that it is peripheral and has little impact on the system. These network measures indicate that positional significance of banks in the interbank network is not just a determinant of systemic risk but also a factor of size or market share. The more central banks are highly centralized, the greater the ability of propagating shocks, which is in line with the positive net spillovers in Banks A and C.

When viewed in combination, the findings of Tables 5 and 6 indicate that there is a close correlation between network centrality and systemic impact. Banks that have higher degree, betweenness and closer centrality are also the biggest net contributors of volatility which proves that structurally central institutions are important nodes that transmit risks. Notably, these findings reveal the possible neutralizing impact of operational efficiency and ESG practices: when systemically important banks implement effective governance and sustainability practices, they can lessen their beta exposure, as well as their ability to spread shocks across the network. This two-fold view, spillover and network centrality, shows that systemic risk management should be considered in both the specifics of individual banks and the overall network, offering practical information to regulators and policymakers in emerging markets.

Table 7: Network Centrality Metrics (Systemically Important Banks)

Bank ID	Degree Centrality	Betweenness Centrality	Closeness Centrality
Bank A	0.82	0.45	0.79
Bank C	0.78	0.50	0.75

Bank ID	Degree Centrality	Betweenness Centrality	Closeness Centrality
Bank B	0.65	0.32	0.68
Bank E	0.60	0.28	0.64
Bank D	0.55	0.22	0.60

Notes: Higher values indicate stronger systemic influence in the banking network.

5. Conclusion and policy recommendations

This study examined the determinants of systematic risk in the Pakistani banking industry by applying the conventional CAPM model to operational factors, including bank size, efficiency, market share, and competition, as well as sustainability factors in terms of ESG performance. The empirical evidence suggests that bigger banks and those with larger market share bear more systematic risk, which proves the hypothesis of too-big-to-fail and demonstrates that large banks increase the volatility in the market as a whole. It was identified that operational efficiency minimized systematic risk, and it showed that more efficient banks are in a better position to absorb shocks. ESG performance is a negative influence on systematic risk, which demonstrates that sustainability practices have a protective effect. The correlation between ESG and operational features indicates that high levels of ESG practices reduce the threat of increased bank size and strengthen the stabilizing impact of efficiency. Systematic risk is more pronounced during crisis periods, and ESG and efficiency work together to reduce this impact, exemplifying the multiplied impacts of operational and sustainability practices during stress. Network centrality and spillover analysis showed that structurally central banks transmit risk disproportionately, which indicates the need to consider both the individual bank properties and their location in the interbank network to assess systemic risk. Altogether, the paper shows that the combination of operational and ESG aspects of systemic risk assessment can be a complete picture of the stability of the banking sector in the emerging markets. To ensure that shocks are not spread, regulators need to focus on large, systemically important banks. Banks must be motivated to maximize operational efficiency by enhancing cost management and asset utilization because this will make them less vulnerable to market fluctuations. Risk management frameworks such as green lending standards, climate risk disclosures, and sustainability reporting can be improved by incorporation of ESG practices to enhance resilience. Stress-testing models that consider both operational, ESG, and network aspects can be used to detect vulnerabilities prior to crises. By integrating size-based requirements with network centrality measures, regulators can pinpoint banks that might have an inappropriate impact on systemic stability. Financial stability can be supported by supporting ESG-linked lending and investment screening, as well as sustainable banking practices, which also help to achieve larger developmental goals.

The research is limited by the fact that crisis periods are analyzed only in 2008 and 2020, which might be inadequate to include the variety of market stress situations. The measures of network centrality and spillovers rely on the correlations of returns and might not capture all the channels of the systemic risk spreading. Future studies may explore the individual impact of Environmental, Social and Governance pillars on systemic risk, investigate other operational variables including liquidity, leverage and governance quality and include dynamic network effects to capture how interbank exposures vary over time. It may be possible to generalize the findings by expanding the framework to other emerging markets.

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Analysis of Interstate Income Inequality of India in Post Reforms Period: An Application of Decomposition Analysis

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Abstract: The study examined the trends in income inequalities across states in the post reforms period by estimating the family of generalized entropy indices. The findings revealed that all of the entropy indices showed an increasing trend in income inequality among states from 1993-94 to 2019-20. However, the speed of this changing dynamics of income inequality differs significantly in the various sub-periods subject to changing government policy and various other exogenous factors. Interestingly, the agricultural sector has a minimal impact on overall income inequality in India, suggesting that promoting faster growth in agriculture can lead to more inclusive economic development, given its potential for high employment generation. Additionally, the study found that the industrial sector's contribution to both economic growth and aggregate income inequality has been declining continuously. In the post-reforms period, often referred to as the era of service-led growth, the service sector not only contributes increasingly to the country's economic development but also plays a dominant role in driving aggregate income inequality.

Key words: Income inequality, decomposition analysis, economic growth, India, Inequality Index Decompositions.
JEL Codes: D63, O15, R12.

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Introduction

Economic inequality has taken a prominent position in public discourse, particularly due to a notable increase during the ongoing Covid-19 pandemic. This surge in inequality is underscored by a significant number of workers in informal sectors losing their jobs, juxtaposed with a substantial increase in earnings for a select few large corporations, (Ferreira 2021). There is a recent surge of interest among policymakers and researchers in understanding the dynamics of inequality. Reducing income inequality within various levels of economic development stands as a paramount objective for Indian policymakers. Economic growth emerges as the preeminent catalyst for alleviating poverty, enhancing the quality of life, and mitigating income disparities in developing nations. Compelling evidence from both international cross-country research and contextual analyses at the national level underscores the imperative of swift and sustained development to expedite progress toward achieving the Millennium Development Goals. A robust discourse surrounds the impact of economic reform on income inequality in developing economies like India, Brazil, and China, primarily rooted in these nations' traditional concerns prioritizing equality over efficiency. It is evident that economic growth serves as a potent force in the substantial reduction of poverty. The widening income disparity among states acts as an obstacle to achieving balanced economic growth, negatively affecting the socio-economic conditions of an economy. Elevated inequality hampers overall growth by limiting the capabilities of lower-income groups while bolstering the capacity of higher-income groups to maintain well-being and accumulate both physical and human capital (Galor, O., & Moav, O. 2004). The growing disparity can be attributed, in part, to structural variations among states. In less developed states, a significant segment of the population relies heavily on agriculture, whereas in more advanced states, a substantial portion of the population is involved in the secondary and tertiary sectors to sustain their livelihoods. For instance, in Bihar, more than 70 percent of the labor force is employed in agriculture, despite 90 percent of the state's population residing in rural area (T sujita et al. 2010). As development progresses, increasing urbanization brings forth potential traps of inequality in income, consumption, housing, assets, education, health, and unemployment. Urban areas, integral to the development process, serve not only as locations where inequality processes unfold but also as modes of production and reproduction (Bhan and Jana, 2015). The objective of this study is to measure and analyze the interstate income inequality in India in the post-reforms period. In 1991, the Government of India started the process of economic reforms broadly focused on liberalization, globalization, and privatization of the Indian economy. The main agenda of these so-called economic reforms is to drive the economic development of India to the new heights. Undoubtedly, the country had been growing at faster rate of economic growth until 2008 when Global Financial Crisis started from United States of America, hit the globe. Since then, the global economy is experiencing the recession and evidently, India is not an exception to it. Apart from it, Indian economy has experienced many policy changes like demonetization, implementation of goods and services tax (GST), end of five year plans and may other changes in recent years. All of these changes have a great impact on India’s growth prospects as well as on the dynamics of interstate income inequality. In this changing scenario, it is important to study the trends and composition of interstate income inequality for policy implications. Further, process of economic development acts as a destabilizing factor in many ways. For instance, as the economy grows at a faster rate, the economic inequalities also grow due to the concentration of wealth in favour of the rich, which is a well known fact established by distributional theories of macro economics (e.g. Kalecki, 1938 and Kaldor, 1980). Therefore it is necessary to examine the dynamics of economic inequalities and economic growth from the perspective of economic theory as well as policy. At this background, this chapter attempts to measure

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and analyze the interstate economic inequality in India in the post-reforms period.This research contributes to the existing literature on income inequality by offering a comprehensive analysis of the interstate dynamics in the context of post-reform India. The findings are expected to inform policymakers, economists, and development practitioners, facilitating the design of targeted interventions to reduce economic disparities and promote equitable growth across regions. The paper has five sections including the present one. Section 2 presents a brief review of latest existing empirical literature on income inequality. Section 3 discusses methodological aspects. Section 4 attempts to measure and analyze aggregate interstate income inequality based on various indices, aiming to account for sectoral contributions to the overall interstate inequality. Finally, Section 5 concludes with policy implications.

Review of literature

As far as income or economic inequality in India is concerned, a large volume of empirical literature is available in this regard. However, only a few studies are available on the decomposition analysis of income inequality. In this section, an attempt has been made to review the most recent and relevant empirical literature in this regard.

Khan (2015) utilizes a commonly employed method to analyze the factors contributing to inter-state disparity in India over the past two decades (from 1993-94 to 2012-13). The research employs a Gini coefficient based decomposition analysis to examine the specific contributions of different sectors to the variation in per capita Net State Domestic Product (NSDP) among states. The findings indicate that the inter-state disparity in per capita NSDP has increased throughout the study period. The decomposition analysis reveals that the service sector plays a significant role in widening this inter-state disparity. The industry sector also contributes to the overall inequality of per capita NSDP, although to a lesser extent than the service sector. On the other hand, the contribution of the agriculture sector has declined over the study period. Consequently, focusing on agriculture could potentially help reduce inter-state disparity, as it has a counter-balancing effect.

By analyzing household survey data representative of the entire country and using districts as the lowest level of geographical analysis, Azam and Bhatt (2018) investigate the influence of spatial factors on income inequality in India. Their study focuses on both rural and urban areas and reveals that within-district income disparities are the primary drivers of income inequality in 2011. Notably, in rural India, between-state income differences have a greater impact on between-district inequality. Conversely, in urban areas, within-state income disparities play a more significant role in explaining between-district inequality. Similar patterns are observed when considering consumption expenditure, with relatively lower levels of inequality but consistent trends. Furthermore, by comparing data from 1993 and 2011, they find that while within-district income differences account for the majority of income inequality in rural India during both periods, the share of between-district differences has increased over time. Between-district differences contribute to approximately one-third of the total increase in rural income inequality between 1993 and 2011.

Mishra, Kumar and Sinha (2019) attempt to provide fresh insights into the nature, intensity, and breakdown of inequality changes in India between 2005 and 2012, despite the country's rapid economic growth since the 1980s. The authors focus on income inequality using the Gini coefficient and analyze local inequality using the “ABG” distribution analysis tool. The study examines three inequality parameters (α, β, and γ) to assess changes in income distributions over time. The findings indicate that inequality remains relatively constant at the median level (α), but there is a rise in inequality at the upper

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(β) and lower (γ) ends of the distribution. Additionally, the analysis of inequality decomposition reveals that while income growth contributes to reducing inequality, it is counteracted by the reordering of income, leading to an overall increase in inequality.

A study by Aneja, Barkha, and Banday (2021) examine the behavior of different sectors and their impact on income inequality. Firstly, it estimates the sectoral decomposition of NSDP among various states from 1991-1992 to 2016-2017. Secondly, it analyzes the sector-wise decomposition of regional inequality in terms of per capita income. Finally, it investigates the role of developmental expenditure in regional inequalities, specifically in terms of per capita developmental expenditure across states. According to the empirical results, India has experienced significant growth in per capita income during the post-reform period. This growth has been accompanied by notable changes in the sectoral composition of income. The tertiary sector has emerged as the primary contributor to post-reform growth. When examining sector-specific disparities, it is observed that disparities within the primary and tertiary sectors have decreased, while the secondary sector has experienced an increase. However, overall, the tertiary and secondary sectors have played a more prominent role in exacerbating income inequality among states, while the primary sector has acted as a mitigating factor in bridging this gap.

Das and Srivastava (2021) examine the relationship between land ownership and income inequality among rural agricultural households in India. The study utilizes a national survey of farmers to assess the extent of land and income inequality using various measures such as the Gini coefficient, Palma ratio, and quantile distribution. Additionally, the study explores the impact of different sources of income and various socioeconomic, production theory-related, and geographic factors on overall income inequality among agricultural households at a national level. This is done through the use of regression-based inequality decomposition (RBID) analysis of the income function. The findings suggest that both land and income inequalities are highest in states with advanced agricultural sectors. The RBID analysis reveals that the size of land holdings is the primary driver of income inequality among agricultural households, followed by crop productivity at the household level. Furthermore, the analysis confirms statistically that the proportion of income derived from wages and livestock has a negative relationship with overall inequality among agricultural households.

De and Devi (2023) focus on understanding consumption inequality in urban areas of Manipur, considering unit-level data from the National Sample Survey. They examine the role of spatial factors and household characteristics in shaping inequality patterns. Despite slow per-capita growth, the study finds an increasing trend in the Gini coefficient for the overall state of Manipur. In terms of consumption, the Gini measures show an overall increasing trend between 1993 and 2011, with rural areas experiencing higher inequality levels than urban areas in 2011-2012, which differs from the national trend. Additionally, the per capita income in Manipur is 43% lower than the all-India average in 2019-2020. The study identifies that the within-component, encompassing both within-district and within-sector factors, plays a significant role in overall consumption inequality. Regression analysis reveals that factors such as age, land ownership, and having a regular salary earner in the household contribute to the overall level of inequality in average per capita consumption expenditure.

Among these studies, only two studies (viz. Khan, 2015 and Aneja, Barkha, & Banday, 2021) deals with sectoral decomposition of interstate income inequality, where Khan (2015) utilize the data from 1993-94 to 2012-13. Therefore, only one study is available which utilize the information after the 11the five year plan. After 2012-13, major policy changes like demonetization, implementation of GST, end of five year planning etc. have been taken place. Taking these changes into consideration, the present study extends its

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period of analysis to 2019-20. Therefore, the present study is an attempt to substantiate the findings of the previous studies by using the latest data.

Methodology

Data source and Sample size

India is a Union of 28 states and 8 union territories (UTs) Table B of the appendix. The study basically deals with the interstate income inequality; therefore it includes 26 states out of 28. Two states viz. Meghalaya and Telangana are not included in the sample of the study. Meghalaya is not included due to non availability of data for the period under consideration. As far as Telangana is concerned, it came into existence as a separate state in 2014 and before 2014 it was part of Andhra Pradesh. Therefore the data of Telangana is available 2014 onwards only. Due to this, the study continues to consider Telangana as part of Andhra Pradesh even in the period after 2014. Apart from this, the study includes two union territories viz. Delhi and Puducherry in the sample for two reasons: First, political system of these two UTs is more close to the political system of states. Second, both of these two UTs have significant portion of India's population.

The major data sources include the Annual Survey of Industry (ASI), National Account Statistics (NAS), NSSO, Center for Monitoring Indian Economy (CMIE), and the Handbook of Statistics of the Reserve Bank of India. The data are collected based on the financial year (from 1st April to 31st March).

3.2 Statistical Technique

To fulfill the research objective, we have utilized the Net State Domestic Product at constant prices. Initially, the data undergo transformation to a common base year (2011-12) through the base shifting and splicing method. This method is employed when the previous base becomes outdated and ineffective for meaningful comparisons. Shifting the base allows the series to be expressed in terms of a more recent time period, facilitating the derivation of a new series with an updated base.

Index number for old base/Index number for new base*100

Splicing: - The process of splicing is very easier and is simple and is akin to that used in shifting the base. It is expressed in the form of formula as follows:

$$\text{Splices Index No} = \frac{\text{Index Number of current year}}{\text{Old Index of new base year}} \quad 100$$

Inequality Index Decompositions: Decomposition requires overall inequality to be decomposed (disaggregated) into constituent parts such as sources of income or population sub-groups. A disaggregation of inequality is desirable for both analytic and policy purposes. In this context, two types of decomposition are of special interest: static decomposition, and dynamic decomposition. The static decomposition provides insights into the structure of the overall inequality while the dynamic decomposition sheds light on the causes of changes in inequality.

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However, the exact procedure and benefits of decomposition varies with inequality measure. An analytically rich and practically useful class of inequality measures is that of additively decomposable measures. A sub-set of indices that have certain analytical advantages over other additively decomposable measures is given by the single parameter 'Generalized Entropy' family (Shorrocks 1984):

$$I_\alpha = \frac{1}{n\alpha(\alpha-1)}\sum\left[\left(\frac{y_i}{u}\right)^\alpha - 1\right] \qquad \alpha \neq 0.1$$

Where n is the number of economic units, yi is the income of unit i and μ is the arithmetic mean income. The value of I_α ranges from 0 to ∞ with higher values representing higher levels of inequality. This class includes:

The mean logarithmic deviation,

$$I_0 = \frac{1}{n}\sum \log \frac{\mathrm{u}}{\mathrm{y_i}}$$

The Theil coefficient

$$I_1 = \frac{1}{n}\sum \frac{\mathrm{y_i}}{\mathrm{u}} \log \frac{\mathrm{y_i}}{\mathrm{u}}$$

The monotonic transformation of coefficient of variation

$$I_2 = \frac{1}{2nu^2}\sum (y_i - u)^2 = \frac{1}{2}cv^2$$

This study uses I_2 index which possesses the most desirable decomposition properties (Jenkins 1995), besides having easy economic interpretation.

Decomposition by Income Sources (sectoral decomposition): Suppose income y_i of economic unit (region) i comes from different sources (or sectors). Let y_{is} denote the income of unit i from source s (s=1,2. … , S) so that $\sum_s y_{is} = y_i$ and y = (y1, y2, …., yn) represents the distribution of total (aggregate) income. It is then useful to express total inequality I as the sum of source contributions, C_S, i.e.,

$$I_2 = \sum\nolimits_s C_s$$

Where C_S depends on income from source s. A source provides a disequalizing effect if $C_S > 0$ and an equalizing effect if $C_S < 1$.

Now define

$$c_s = C_s / I_2$$

Therefore,

$$\sum\nolimits_s c_s = 1$$

C_S is the absolute contribution of source s to overall (aggregate) inequality, while c_S are its proportional contribution.

The exact procedure for decomposition depends on the measure of inequality, however. For I_2 index, this decomposition is defined as:

$$I_2 = c_s I_2 = \chi_s \rho_S \sqrt{I_2 I_{2s}}$$

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Where χ_s is the share of source s in the total income, ρ_S is the correlation coefficient between income from source s and total income and I_{2s} is the inequality index for distribution of income from source s. So

$$I_2 = \sum_s C_s = \sum_s \chi_s \rho_S \sqrt{I_2 I_{2s}}$$

For the dynamic decomposition, we have

$$\Delta I_2 = \sum_s \Delta C_s = \sum_s \Delta[\chi_s \rho_S \sqrt{I_2 I_{2s}}]$$

Where Δ is the difference operator. And the percentage inequality changes are,

$$\%\Delta I_2 = \frac{100\Delta I_2}{I_2} = \sum_s c_s \%\Delta C_s$$

A large value of $c_s\%\Delta C_s$ suggests that distributional changes in income from sources have a large influence in changes in total (aggregate) inequality (see Jenkins 1995; and Theil 1989 for complete methodology)

Results and Discussion

Analysis of Interstate Inequality in per capita Income

Table 1 and Figure 1 show the trends of aggregate interstate inequality of per capita income measured by 'the family of generalized entropy indices' i.e. the mean logarithmic deviation (I_0), the Theil index (I_1) and the monotonic transformation of the coefficient of variation (I_2). In addition, the table also includes the Gini coefficient (G) because of its popularity among the researchers as the most common index widely used in studies analyzing the economic or income inequality. We have used these four indices for measuring the income inequality to make the results more robust and also to facilitate the cross verification of the results. Since the term 'economic inequality' may be narrowly defined as 'income inequality', we use these two terms interchangeably in this study. It is worth mentioning that all the indices in Table 1 as well as other subsequent tables in this chapter are multiplied by 1000 in order to make the comparisons easy to understand.

Table 1: Inter-state Inequality in per capita NSDP: Various Inequality Indices

	INDEX*1000			
Year	I_0	I_1	I_2	G
1993-94	37	39	117	219
1994-95	37	39	110	220
1995-96	37	39	102	219
1996-97	40	43	121	231
1997-98	41	44	118	234

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1998-99	50	55	170	258
1999-00	49	54	172	256
2000-01	50	55	175	264
2001-02	49	53	171	260
2002-03	51	56	175	267
2003-04	50	53	161	260
2004-05	52	55	169	267
2005-06	58	59	175	282
2006-07	58	60	175	285
2007-08	57	58	159	282
2008-09	57	58	153	282
2009-10	63	62	164	297
2010-11	64	64	174	301
2011-12	70	73	220	316
2012-13	*64*	*63*	*166*	*299*
2013-14	*60*	*58*	*136*	*289*
2014-15	68	67	177	307
2015-16	73	72	194	317
2016-17	75	75	211	322
2017-18	75	76	209	336
2018-19	74	75	211	330
2019-20	75	76	214	333

Source: Author's calculation

Table 1 shows that just after the commencement of economic reforms or during the period of 8th five year plan (1992-93 to 1996-97), the aggregate income inequality of per capita income as measured by all four indices roughly exhibited a constant trend. However, at the end of 8th five year plan (i.e.1996-97), the income inequality started to rise. This may be due to the fact that 1991 was the year of financial distress caused by rising oil price due to the gulf war along with large and growing fiscal imbalances over 1980s. This financial crisis forced the Government of India to undertake the economic reforms as per the recommendations of then finance minister Dr. Manmohan Singh. Due to these major economic reforms the GDP growth started to rise and consequently the actual growth rate (6.8%) was recorded much higher than the targeted growth rate (5.6%) during the 8th five year plan. It is a well established fact by Kuznets (1955) that in a developing economy, the rise in per capita income is followed by the rising economic inequalities. This lagged relation between economic growth and income inequality explains the dynamics of aggregate interstate economic inequality over the period of 8th five year plan (1992-93 to1996-97). That is, the stagnant economic growth of pre-reforms period was a major factor behind this constant trend in income inequality. During the 9th five year plan (1997-98 to 2001-02), the interstate income inequality was continued to rise due to the remarkable economic growth made in the 8th five year plan. However, a sudden drop had been observed in the trend of aggregate interstate income inequality in terms of all four indices in the last year of 9th five year plan (i.e. 2001-02). One possible explanation of this fall in income inequality may lie in the fact that the actual growth rate of GDP (5.4%) during 9th plan was not only below the targeted growth rate (6.5%) but also below the growth rate of 8th five year plan. It is worth

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mentioning that one must keep a basic precaution in mind while interpreting such results on the basis of economic theories since economic variables do not always behave in a way as predicted by economic theories as many other economic and non-economic variables remain continuously in operation and therefore disturb such theoretical relations.

It is interesting to note that the income inequality demonstrated a continuously rising trend for the period 2002-03 to 2011-12 in terms of all four indices of inequality. The period includes two five year plans (i.e. 10^{th} and 11^{th}). The 10^{th} and 11^{th} five year plans are known as the period of continuously rising growth rate of GDP. The average growth rate was observed 7.6% in 10^{th} five year plan (2002-03 to 2006-07), which increased to 8% in 11^{th} five year plan (2007-08 to 2011-12). It is the highest growth rate ever achieved in the economic history of India since Independence. Therefore, the rise in the level of interstate inequality was quite natural in the period of high economic growth i.e. the period of 10^{th} and 11^{th} five year plans. However, a sudden decline had been observed during the initial two years (i.e. 2012-13 and 2013-14) of 12^{th} five plan which may be due to the fact that during these two years the growth rate of GDP was recorded very low (e.g. below five percent) due to the recessionary pressures followed by the global financial crisis. This sluggish growth had been continued to 2019-120. An interesting fact has been emerged from the data in Table 1 that for the period from 2014-15 to 2019-20, the income inequality was continuously rising despite the slow growth rate over this period against the hypothesis proposed by Kuznets which states that a higher growth rate of income leads to a higher level of economic inequality and vice-versa. It may be possible due the fact that in this period, the Indian economy has undergone some major changes. Some of these changes may be outlined as: first, since after the global financial crisis of 2008, the world economy is experiencing slowdown in economic growth. However, India is less affected by this crisis, the adverse effects of this slowdown on the Indian economy is certainly unavoidable. Second, in 2015 the Government of India dissolved the Planning Commission and replaced it with a new institution named NITI Ayog. In this way, the Indian economy has entered into a new era named as post planning period. Currently, there is no planning commission and no ongoing five year plan. The first change along with some other changes viz. demonization, implementation of GST etc. may be responsible for the low growth rate of GDP in this period. On the other hand, the end of planning process may be responsible for the rising trend of interstate income inequality in post planning period. Since, one of the main objectives of the five year plans is to promote the balanced regional and sectoral growth of the economy. In this way the five year plans not only helped the economy to move on the path of economic development, but also acted as an offsetting factor as far as regional inequalities are concerned. Therefore, both of these changes on *a priori* ground may be responsible for falling growth rate along with rising inequality.

Analysis of the Sectoral Contributions to Aggregate Income Inequality

In section 4, we have analyzed the dynamics of interstate income inequality from the perspective of economic development. In economics, merely focusing on one aspect in order to explain the trends of income inequality is not only inadequate but also unsatisfactory. Therefore, in order to understand the inner mechanism of interstate income inequality, it necessary to investigate the structural and sectoral changes which the Indian economy has been experiencing in the post reforms period. For this purpose we have chosen I_2 index among the other indices explained in section 4 Since all four indices exhibits almost similar trends in the interstate income inequality, the preference for I_2 index over the other indices may

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not be considered objectionable. Moreover, a significant advantage of choosing the I_2 index is that it is easy to decompose into various components and in this way it helps to understand the inner structure of economic inequality. The results of sectoral decomposition of interstate inequality have been demonstrated in Table 2 which accounts for the sectoral contributions to aggregate income inequality.

Table 2: Sectoral Contribution to Inter-state Inequality in Post-Reforms Period: Static Decomposition

Year	Aggregate Inequality ($1000I_2$)	Absolute sectoral contribution ($1000C_k$)			Percentage sectoral contribution ($100c_k$)		
		Agriculture	Industry	Services	Agriculture	Industry	Services
1993-94	117	4	69	44	3	59	37
1994-95	110	3	64	43	2	58	40
1995-96	102	3	58	42	3	56	41
1996-97	121	2	69	50	2	57	42
1997-98	118	-1	69	51	-1	58	43
1998-99	170	-0	104	66	-0	61	39
1999-00	172	2	103	68	1	60	39
2000-01	175	0	106	69	0	61	39
2001-02	171	-2	106	67	-1	62	39
2002-03	175	-1	108	68	-0	62	39
2003-04	161	-2	102	61	-1	63	38
2004-05	169	2	102	65	1	60	38
2005-06	175	3	104	68	2	60	39
2006-07	175	1	104	69	1	60	40
2007-08	159	2	90	66	1	57	42
2008-09	153	1	83	69	1	54	45
2009-10	164	1	91	72	0	56	44
2010-11	174	1	97	77	0	56	44
2011-12	220	2	122	97	1	55	44
2012-13	166	1	84	81	1	51	49
2013-14	136	2	64	70	1	47	51
2014-15	177	2	87	88	1	49	50
2015-16	194	1	98	94	1	51	49
2016-17	211	2	109	100	1	52	47
2017-18	209	2	107	100	1	51	48
2018-19	211	2	107	102	1	51	48
2019-20	214	2	108	104	1	50	49

Source: Author's calculation

Note: $C_k = (\chi_k \rho_k \sqrt{I_2 I_{2k}})$, $c_k = (C_2/I_2)$

Table 2 shows the absolute and percentage contributions of agriculture, industry, and service sector to the aggregate interstate inequality as measured by I_2 index. The addition of these absolute sectoral

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contributions gives the I_2 index itself. The table shows that in the period of 8th five year plan (1993-94 to 1996-97), the industrial sector had emerged as the biggest contributor to aggregate interstate inequality followed by service sector and agriculture sector. In this period the contribution of industrial sector ranges from 56 to 59 percent. Thus, the industrial sector was largely responsible for the changes in interstate income inequality in this period. After the industrial sector the service sector was the second largest contributor to aggregate inequality and the contribution of service sector ranges from 37 to 42 percent over the period from 1993-94 to 1996-97. It is interesting to note that the agriculture sector had the smallest contribution during this period as opposed to industry and services. The contribution of agriculture sector rages from 2 to 3 percent during 8th five year plan.

In the period of 9th five year plan (1997-98 to 2001-02), the absolute as well as percentage contribution of industrial sector was continuously increasing, however, the rate of increase was very slow, whereas the percentage contribution of service sector remained almost constant (around 39 percent) despite the increase in its absolute contribution to aggregate inequality over this period. It is due the fact that the increase in the absolute contribution of service sector was so insignificant that it could not increase its percentage contribution. One interesting fact from Table 2 has been emerged that the percentage contribution (and also absolute contribution) of agriculture sector was either negative or zero over the period of 9th five year plan. A negative contribution implies that the agriculture sector acts towards reducing the interstate income inequality.

From 2002-03 to 2019-20, the absolute as well as percentage contribution of industrial sector roughly shows a declining trend while the contribution of service sector both in absolute and percentage terms has been increasing continuously. In 2019-20, the contributions of both sectors become almost equal. For instance, in 2019-20, the percentage contribution of industrial sector to aggregate inequality is decreased to 50 percent while the contribution of service sector is increased to 49 percent. On the other hand, the percentage contribution of agriculture sector to aggregate inequality is either one percent or below over the period from 2002-03 to 2019-20.

From perspective of economic policy, the following facts have been emerged from the sectoral decomposition of interstate income inequality as demonstrated in Table 2: First, agriculture sector has negligible contribution to aggregate income inequality in India. It implies that the faster growth of agriculture sector can ensure the more inclusive economic development of India since the growth of agriculture sector undoubtedly reduces the level economic inequality by providing the employment to the largest section of the rural population which constitutes approximately 70 percent of total population of India. Second, the role of industrial sector is continuously declining in economic growth as well as in aggregate income inequality. Third, in the post reforms period which is also known as the period of service led growth, the service sector is not only increasingly contributing to the economic development of the country but it also playing a dominant role in increasing the aggregate income inequality. This is due the fact that the employment potential of service sector is much lower than that of agriculture and industrial sector. Therefore the growth of service sector does not boost the process of employment generation. That is the reason why we sometimes call this ‘service led growth’ as ‘jobless growth’. Here, it is important to mention that the results of sectoral decomposition of inequality of this study are completely consistent with the findings of Khan (2015) and Aneja, Barkha, & Banday (2021).

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Concluding Remarks and Policy Recommendations

In this paper, we examined the trends in income inequalities across states in the post reforms period by estimating the family of generalized entropy indices. The results indicate that all of the entropy indices (including Gini-coefficient) exhibit an increasing trend in interstate income inequality in India in over the period from 1993-94 to 2019-20. However the speed of this changing dynamics of income inequality differs significantly in the various sub-periods subject changing government policy and various other exogenous factors. The economic reforms started in 1991 undoubtedly fasten up the speed of India's economic growth but at the cost of rising income inequality which seems to fade the dream of inclusive growth as documented in the draft of 11^{th} and 12^{th} five year plans. In order to understand the structure of India's economic inequality, the sectoral contribution in the rising income inequality over the period are also investigated. For this purpose we decomposed I_2 index into three mutually exclusive components where each component explains the absolute as well as relative contribution of agriculture, industry and service sector to the aggregate income inequality. It has been found that agriculture sector has negligible contribution to aggregate income inequality in India. It implies that the faster growth of agriculture sector can ensure the more inclusive economic development of India due to its high employment potential. It has been also found that the role of industrial sector is continuously declining in economic growth as well as in aggregate income inequality. Further, in the post reforms period which is also known as the period of service led growth, the service sector is not only increasingly contributing to the economic development of the country but it also playing a dominant role in increasing the aggregate income inequality. This is due the fact that the employment potential of service sector is much lower than that of agriculture and industrial sector. Therefore the growth of service sector does not boost the process of employment generation. That is the reason why we sometimes call this 'service led growth' as 'jobless growth'.

To address income inequality at the state level, tailored initiatives are crucial. Firstly, there is a need for State-specific Skill Development Programs, focusing on designing and implementing vocational training programs that align with each state's economic needs. This ensures that the local workforce possesses skills in demand by regional industries. Secondly, addressing the unique challenges of each state's farming community through agricultural reforms is vital. State-level initiatives, including improvements in irrigation, crop diversification, and enhanced market access, aim to bolster the resilience and sustainability of the agricultural sector. Thirdly, Customized Industrial and Infrastructure Development is essential. Tailoring plans to each state's strengths involves identifying and promoting sectors where a state has a comparative advantage, fostering economic growth in line with regional capacities. State-level policies promoting entrepreneurship, innovation, and the growth of small and medium enterprises contribute to local economic development. Additionally, implementing education reforms specific to each state is crucial. This includes initiatives to enhance school infrastructure, teacher quality, and access to educational resources, contributing to overall human capital development. Finally, Local Governance Empowerment is imperative for inclusive development. Strengthening local governance structures and encouraging community participation in decision-making processes, possibly through decentralization, fosters inclusive development initiatives.

Ethical approval and consent to participate

The research was conducted using data available in the public domain and did not include any human participants or animals. Therefore, no ethical approvals were required.

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The authors of the study have consent and responsibility for submission to the journal.

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The authors declare that they have no conflict of interest.

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Authors Contributions

Parveen Kumar: - Conceptualization, Methodology, Analysis, and Writing
Ombir singh: - Editing, supervision, data handling

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Appendix

Table A: Decomposition of Absolute Sectoral Contributions to Inter-State Inequality

Year	Agriculture				Industry				Services			
	C_{Agri}	ρ_{Agri}	χ_{Agri}	$I_{2\,Agri}$	C_{Ind}	ρ_{Ind}	χ_{Ind}	$I_{2\,Ind}$	C_{Serv}	ρ_{Serv}	χ_{Serv}	$I_{2\,Serv}$
1993-94	0.004	0.132	0.22	0.138	0.069	0.87	0.37	0.214	0.044	0.704	0.41	0.152
1994-95	0.0027	0.093	0.22	0.132	0.064	0.875	0.37	0.198	0.043	0.766	0.41	0.137
1995-96	0.0033	0.125	0.21	0.126	0.058	0.853	0.37	0.184	0.042	0.757	0.42	0.132
1996-97	0.0019	0.066	0.21	0.137	0.069	0.852	0.37	0.219	0.05	0.765	0.43	0.152
1997-98	-0.0015	-0.06	0.19	0.132	0.069	0.831	0.39	0.213	0.051	0.777	0.43	0.153
1998-99	-0.0001	-0.004	0.18	0.139	0.104	0.887	0.39	0.301	0.066	0.731	0.43	0.21
1999-00	0.0017	0.062	0.17	0.161	0.103	0.876	0.38	0.309	0.068	0.706	0.44	0.219
2000-01	0	0	0.17	0.156	0.106	0.875	0.39	0.156	0.069	0.699	0.45	0.156
2001-02	-0.0016	-0.064	0.17	0.147	0.106	0.877	0.39	0.31	0.067	0.677	0.45	0.22
2002-03	-0.0007	-0.031	0.15	0.151	0.108	0.879	0.4	0.307	0.068	0.694	0.45	0.218
2003-04	-0.0015	-0.064	0.16	0.146	0.102	0.875	0.4	0.291	0.061	0.675	0.44	0.205
2004-05	0.0021	0.091	0.15	0.154	0.102	0.868	0.41	0.287	0.065	0.717	0.44	0.206
2005-06	0.003	0.139	0.14	0.154	0.104	0.868	0.41	0.292	0.068	0.727	0.45	0.208
2006-07	0.0014	0.065	0.13	0.166	0.104	0.859	0.41	0.295	0.069	0.734	0.45	0.209
2007-08	0.002	0.094	0.13	0.164	0.09	0.833	0.41	0.264	0.066	0.758	0.46	0.189
2008-09	0.0013	0.069	0.12	0.157	0.083	0.813	0.4	0.255	0.069	0.79	0.48	0.182
2009-10	0.0008	0.046	0.11	0.158	0.091	0.832	0.41	0.267	0.072	0.782	0.48	0.192
2010-	0.0006	0.033	0.11	0.165	0.097	0.839	0.4	0.289	0.077	0.777	0.49	0.202

11												
2011-12	0.0018	0.088	0.11	0.186	0.122	0.877	0.4	0.348	0.097	0.795	0.49	0.249
2012-13	0.0011	0.059	0.11	0.169	0.084	0.84	0.38	0.263	0.081	0.84	0.51	0.189
2013-14	0.002	0.11	0.11	0.165	0.064	0.799	0.37	0.216	0.07	0.861	0.52	0.156
2014-15	0.0018	0.101	0.1	0.178	0.087	0.822	0.37	0.286	0.088	0.834	0.53	0.199
2015-16	0.0015	0.094	0.09	0.177	0.098	0.834	0.38	0.309	0.094	0.83	0.53	0.214
2016-17	0.0018	0.117	0.09	0.171	0.109	0.845	0.39	0.331	0.1	0.813	0.52	0.237
2017-18	0.0024	0.148	**0.08**	0.203	0.107	0.836	**0.39**	0.328	0.1	0.813	0.53	0.232
2018-19	0.0024	0.146	0.08	0.205	0.107	0.84	0.4	0.318	0.102	0.815	0.52	0.241
2019-20	0.0025	0.142	0.09	0.196	0.108	0.84	0.39	0.336	0.104	0.814	0.52	0.246

Source: Author's calculation

ρ_k= Sectoral correlation with aggregate income, χ_k= Sectoral share in aggregate income, $I_{2\,k}$= Sectoral inequalities

Table B: List of the states and Union Territories of India

Sr. No.	Name of the States
1	Andhra Pradesh, Arunachal Pradesh
2	Arunachal Pradesh
3	Assam
4	Bihar
5	Chhattisgarh
6	Goa
7	Gujarat
8	Haryana
9	Himachal Pradesh
10	Jharkhand
11	Karnataka
12	Kerala
13	Madhya Pradesh
14	Maharashtra
15	Manipur
16	Meghalaya
17	Mizoram
18	Nagaland
19	Odisha
20	Punjab

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21	Rajasthan
22	Sikkim
23	Tamil Nadu
24	Telangana
25	Tripura
26	Uttar Pradesh
27	Uttarakhand
28	West Bengal
	Union Territories
1	Andaman and Nicobar Islands
2	Chandigarh
3	Dadra and Nagar Haveli and Daman and Diu
4	Lakshadweep
5	Delhi (National Capital Territory of Delhi)
6	Puducherry
7	Jammu and Kashmir
8	Ladakh

Note: - Meghalaya and Telangana have been excluded from this study. Additionally, our focus is narrowed down to only two union territories in India: Delhi and Puducherry.

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Women in STEM workforce: Review from Southeast Asian Economies

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Abstract

Science and technology has been considered a male-dominated profession with women holding fewer leadership positions. They are universally under-represented in STEM (Science, Technology, Engineering, Maths) fields. Retaining women in education and, hence, careers in science is essential for an economy's national development. They can bring a different outlook for every sphere by making it more diverse and leading to women's empowerment. A review of the literature has been done to determine the participation of women in the STEM workforce with a particular focus on Southeast Asian economies, which mainly comprise of the developing nations. The study identifies the reasons for women not being able to climb the hierarchical ladder in scientific careers. Furthermore, the initiatives taken by these nations to increase the participation of women in the STEM workforce have been discussed, followed by Interventions by the United Nations on this pertinent issue.

Keywords: Gender Studies, Leadership in STEM, Southeast Asian studies

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1. Introduction

For an economy to progress, Science, technology & innovation (STI), and human development are crucial, women represent almost half of the global population, and they can contribute a major strength to the socioeconomic development of a nation. They are a vital human resource and pillars of the world economy. They have contributed in almost every sphere of life by being powerful agents of change. They are even leading the country (women president, speaker, etc), being a source of inspiration to many. In this context, the far-reaching benefits of diversity and gender parity in leadership and decision-making are increasingly being recognized in all spheres. Women as leaders and decision makers ultimately play a critical role in advancing gender equality and furthering the nation's economic, social and political progress. Therefore, their contribution should not be ignored, and they must be represented in decision-making in businesses, educational institutions, communities, and politics not because of gender parity but because of their merit. Sadly, the S&T sector, which is considered a key element in the economic growth of a nation, is heavily male-skewed. Traditionally, it has remained a male-dominated area in many parts of the world where men still occupy the top positions. The presence of women in higher positions of power in this sector is still an exception. The growth in the fraction of women in S&T has been slow for many decade s (International Day of Women and Girls in Science). We need to understand that building scientific capacity is a shared responsibility and, in this regard, a serious concern has been raised since the 1970's for the inclusion of women and gender parity in S&T under the auspices of UN seminars, conferences being organised nationally and internationally. Delegates drafted the UNDP Beijing Express Declaration for advancing women's equality and opportunities at the Fourth World Conference on Women, Beijing, China, in 1995 where women's empowerment was at the forefront (UN, 1995). Since then, policymakers and planners have recognised the importance of women in leadership positions and efforts are being made. Developing nations that have made commendable progress have done it primarily through empowering women. So, the full involvement of women in scientific and technological endeavors is essential for rapid national development and the sustainable happiness of the people. Because of the persistent efforts by the governments of different nations, the number of women in leadership positions is on the rise from a local to a global level.

Despite some progress, women scientists are paid less, promoted less frequently, and more likely to quit research careers than men of similar qualifications (Inter-Academy Panel on '*Women in Science in India*', 2016). Inclusivity and diversity in leadership positions are important as they bring a fresh perspective to decision-making. Empowering professional women and women at the rural and grassroots levels of developing countries is necessary. Women in rural areas need to be valued as a precious human resource and not a liability as they can change the social stigmas of the society by their upliftment through science

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and technology, thereby, questioning the societal norms of the patriarchal mindset where head of the family is generally perceived to be a male, relationship between work and family which act as hurdles for women in science. They even join the labour market, but their number dwindles as they move up at the organisational ladder. In the engineering sector in many nations, the situation is even worse, where the participation of women in education and employment is low.

2. Review of Literature

Articles were searched from the Google Scholar database with the following search terms used; 'Women in STEM workforce', 'Barriers to women in STEM', Women in STEM workforce in South East Asia', 'Gender inequality in STEM professions in South East Asian economies', etc. Separate searches for this particular topic have been done for the ten members of ASEAN, i.e., Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.

2.1 Participation of Women in the STEM workforce

Historically, women need to be more adequately represented in Science, Technology, Engineering, and Mathematics (STEM) education, leading to a corresponding underrepresentation in the STEM workforce (Landivar L. C, 2013). As per a 2017 report, women account for just 30% of STEM students in higher education worldwide (UNESCO, 2017). The absence of women in STEM organizations may lead to a lack of diverse perspectives, hindering the generation of innovative ideas. Homogeneous workforce in STEM are less likely to navigate effectively in dynamic and varied environments. Consequently, advocating for educational and career opportunities for women is viewed as a strategy to tap into the full potential of the entire pool of STEM innovators (Pearson et al., 2015). While Western countries have progressed towards more egalitarian social structures, many Asian countries still largely adhere to patriarchal social value systems (Mukhopadhyay & Seymour, 2021). Globally, efforts are underway to boost women's involvement in STEM education, civic engagement, and the STEM workforce. Some Asian countries have witnessed significant strides, with women notably increasing their presence in specific STEM fields, such as computer science and computer engineering (Fan & Li, 2005). Historically, educational opportunities, especially in STEM fields, have favored males over females. While Western countries have shifted towards more egalitarian social structures, many Asian countries still maintain predominantly patriarchal social value systems (Mukhopadhyay & Seymour, 2021). In the face of gendered challenges, numerous Asian women persist in pursuing STEM careers, navigating male-dominated work environments daily. Despite increased representation in specific STEM fields, women in many Asian countries often encounter limited access to leadership positions (Campion & Shrum, 2004). Excluding women from STEM organizations risks overlooking valuable innovative ideas. Homogeneous

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workforces struggle in dynamic, diverse environments. Thus, promoting educational and career opportunities for women is seen as essential to harness the potential of STEM innovators fully (Pearson et al., 2015).

In India, participation of women up to Ph.D. is about 20-25%, but in the positions of Professors or Heads of departments/divisions, it falls to 10-12% (Inter-Academy Panel on '*Women in Science in India*', 2016). Because of the trickle-down effect of few role models for women engineering students, there is a dearth of academic women engineers in visible leadership positions, which is responsible for their under-representation in academia, industry, and government. We need women in science at every level. According to a study on women in leadership, women spend more time contributing to diversity, equity, and inclusion efforts, 07% of men as compared with 11% of women (Forbes, 2021). Encouraging women faculty to consider formal leadership positions and providing structured opportunities to explore those options will likely result in those faculty members' participation as academic leaders (O'Bannon et al., 2020). Working women engineers have found less stress in managing work-life balance, and the gender parity index for women in science is more than one. Very few numbers of women engineers are in the decision-making positions. The employment of women engineers has increased, but they are primarily concentrated in the lower levels because they feel that the workplace is very masculine and they do not feel very comfortable in an organisation.

2.2 Reasons for women remaining in the lower levels of hierarchy in scientific fields

Women scientists face innate prejudice and bias in the workplace. Patriarchal norms contribute to gender discrimination challenges. There is widespread gender insensitivity, which exacerbates workplace issues, and explicit sexual harassment remains a pervasive problem. Gender is embedded in the socio-cultural rules of a workplace, and certain practices are biased towards men, which hinders the chances of women to get to the top (Gupta, 2017a). Women perceive themselves to be more fit in the managerial roles unlike men who consider themselves apt for technical roles because of gender stereotypes (Naukkarinen & Bairoh, 2022). In the case of CSIR laboratories, despite a significant contribution by women scientists in the output, they have not been able to reach the position of a head because of lack of visibility in the organization. (Namrata Gupta, 2014). They do not move up the ladder at the same place as men despite having the same experience as their male colleagues. (Gupta, 2017b) . A possible reason for this is the Indian culture, which requires women to devote time to family, thereby making them less productive in the perception of the males working in research organizations. Also, men remain in the upper posts because sexism exists in the work environment and is ignored by both men and women. (Bevan & Learmonth, 2013) . It was observed that women were more coordinated and the ones who shared

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information with all. They were satiated with their current position with low expectations to move up the ladder, unlike optimistic men (Dhawan, 2000). Another reason why women scientists are at the lowest levels is the inability to protest against wrongdoing and the lack of motivation. (Chakravarthy et al., 1988). Unconscious gender bias existed in institutions when women who were well-accomplished asked for laboratory space, financial resources, and awards to be granted based on merit. (Holliday et al., 2015). Women scientists are rarely appointed as the chairman of various committees in the research institutes and are very few at the top level of the hierarchy. (Namrata Gupta, 2020). They are smaller because of the existence of patrifocal social norms. (Gupta & Sharma, 2003a). Age could be a reason for women in the middle ranks being more productive in research than men because of less burden with grown-up children, and it tends to be even higher after they reach 50's as now they are free to devote time to research.(Gupta & Sharma, 2003b). Because of the belief that women face a dual burden of work and homely responsibilities, they are considered less productive in the workplace. This could be because of the total time devoted, which could be reduced due to family responsibilities or staying back at odd hours, etc. The younger male scientists did support their wives, who were also scientists, in sharing the household responsibilities and taking care of the family, but they did accept that despite their changes in thinking, the stereotypes still existed at the workplace. Apart from this, the social and cultural background of women determines their entry into science. The more educated parents with higher incomes encourage women's entry into male-dominated fields like science, but in the later stages of their careers, it does not affect them in any way. (Kumar, 2001). Many women researchers in STEM distance themselves from other women in the workplace whom they feel are overreactive to gender bias issues or who counter them because these women feel that because of countering the conflicts, it rather leads to their exacerbation and not the resolution of those issues (Rhoton, 2011). In India, unlike other nations, there is a belief that women are equally capable of doing science. In fact, if we look at the no. of publications, women are not behind men, but in spite of this, the workplace is gendered (Gupta, 2016) . In scientific research organizations, the socio-cultural context plays a crucial role in determining the level of gender bias. Because women are unable to socialize and form informal contacts with those in power, they are discriminated against when it comes to their promotions. This has been evident mainly in the case of junior women scientists (Gupta, 2016). Women in academic science are less than men in terms of faculty. There are more women than men in the position of assistant professor, but very few in the post of professors as compared to men as women are considered warmer and more social, whereas men are considered competent and innovative (Kumar, 2001). Because of lower informal networking, women are less engaged in innovation activities (Chatterjee.S,2018) . They are supposed to maintain their professional identity at the workplace and keep their one aside as it can hamper their professional image as one-woman engineers seem to represent all woman engineers. (Carter & Kirkup, 1990). Patronizing

attitudes of men in the workplace act as a hindrance to the progression of women in terms of collaboration and networking (Subramanian, 2007). It is mainly in academia that females get stuck under one specific male chauvinist head, and there is no option of switching. Interorganisational networks can help women scientists and support them to escape the hierarchical setup. (Smith-Doerr, 2004) . Casual odd-hour meetings, which are unproductive according to women scientists, provide an edge to men in having informal interaction with the ones in power (Gupta, 2017b). It is hard for women in academia to contact industry scientists and file patents (Kjersten Bunker Whittington and Laurel Smith-Doerr, 2008). Informal communication is prevalent in the departments of S&T universities. However, it is a matter of the only boy's club, which gives them an edge regarding networking inside and outside the committee. Socialization is a problem because of the culture of segregation of men and women in the workplace (Gupta & Sharma, 2002). Gender segregation in Turkey's R&D sector is less than any other nation like the US because a boost for women's participation in natural sciences and engineering fields via public education and a gender-neutral university entrance exam has led to a surge in women innovators. (Setenay Nil Dogan, 2015) . Apart from the formal and informal structural constraints, lower funding grants to women compared to men are another reason for their higher attrition rates. They have to depend mainly on personal sources for access to financial capital (Lueg, 2020). Grant funding is important for a scientist as it enhances productivity in the sense that a researcher can use it for training students or staff working under it on a project; it helps expand opportunities to collect data and also in forming more networks or collaboration. (Welch, 2014) . Sadly, gender discrimination exists even in grant funding because of the stereotypes.

2.3 Status of women in Southeast Asia

ASEAN aims to foster economic and security cooperation among its ten members: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. Girls in primary and secondary education in numerous ASEAN Member States (AMS) outperform boys in mathematics and science, but this academic advantage does not always result in their pursuing further STEM education or careers. Although more women enroll in higher education in Southeast Asia than men, they are significantly underrepresented in STEM disciplines. Only one in six STEM students are women, highlighting a pronounced gender gap in tertiary education (ILO, 2016). Although women constitute 39 percent of technology majors, a lower percentage compared to the 56 percent seen in other fields of study, their representation in the region's technology sector is 32 percent. This contrasts their overall presence in the workforce, where women make up 38 percent (Vaishali Rastogi et al., 2020).

Table 1: Percentage of Female Tertiary Education Graduates by Field (WEF 2022)

Country	Percentage of Female Tertiary Education Graduates by Field (WEF 2022)		
	Engineering, Manufacturing, & Construction	Information & Communications Technology	Natural Science, Mathematics, & Statistics
Brunei Darussalam	52.26%	-	73.37%
Cambodia	-	8.44%	34.08%
Indonesia	24.92%	34.67%	-
Lao PDR	17.95%	40.82%	55.00%
Malaysia	27.05%	46.00%	70.73%
Myanmar	42.34%	-	66.38%
Philippines	24.48%	48.13%	61.97%
Singapore	-	32.22%	61.72%
Thailand	-	47.85%	70.72%
Vietnam	-	-	50.59%

Source: World Economic Forum 2022

In recent years, Singapore has witnessed heightened efforts from individuals, social organizations, institutions, and private companies advocating for increased representation of women in STEM (science, technology, engineering, and mathematics) fields. During 2014–2016, various local events aimed to promote women in STEM fields, including STEM Week by the National University of Singapore, STEM Workshop for Women by the Singapore University of Technology and Design, a UN Women's Committee panel discussion, and the Women in Engineering, Science, and Technology symposium by Nanyang Technological University. These initiatives respond to the need to expand the labor force, addressing challenges posed by a shrinking and aging population, as per the Ministry of Manpower (2016). Encouraging women's participation was a strategy to mitigate this issue (Singapore Tripartite Forum, 2022) . In Singapore, while the overall gender ratio is nearly equal, the representation of females in engineering programs is less than 20% (Elaine Lee, 2017). The University of Hong Kong (HKU) leads in gender representation with 28.9% of women leaders, predominantly from non-STEM backgrounds, primarily at the departmental level. HKU also excels with 14.3% female institutional leaders. National Taiwan University follows closely, boasting a notable 24.6% representation of women in leadership, showcasing significant progress in gender equality and university management among East Asian world-

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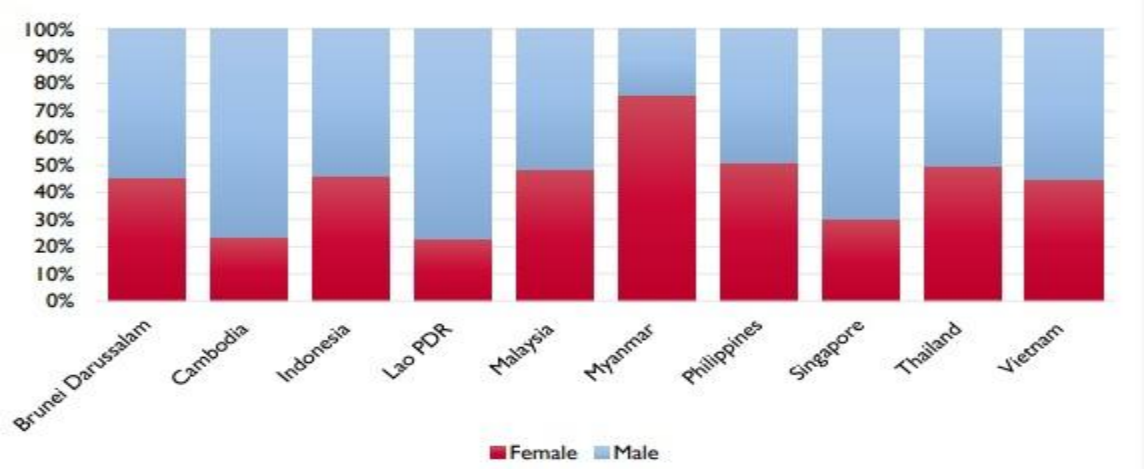
class universities (Hei Hang & Hayes Tang, 2019). Private institutions dominate higher education in Asia (e.g., Japan, South Korea) with up to 80% student enrolment, whereas Latin America, which was historically tied to Catholic-founded private universities, now sees a shift towards for-profit institutions, indicating a growing preference for profit-driven education (Burton Bollag, 2003). Cambodia is amidst an economic transformation amidst the global Industrial Revolution 4.0, creating a heightened demand for STEM graduates. However, the nation encounters challenges in attracting students to STEM fields in higher education. Addressing this requires initiatives not only at the classroom level but also through extracurricular activities in upper secondary schools and broader societal efforts (Jamil et al., 2019) . Cambodian private university academics note the absence of research, citing no institutional requirements. Public universities show limited, locally published research, often diminishing post-masters thesis completion (Heng et al., 2023).

Globally, there is a significant gender disparity among researchers, with men outnumbering women by a ratio of 71:29%. Interestingly, countries with lower research and development expenditures, such as the Philippines and Thailand, have a higher proportion of female researchers, exceeding 45% (UNESCO,2012). Both personal and environmental factors influence academic research engagement and productivity (Kimkong Heng et al., 2020). A conducive environment grants access to essential tools and resources, enhancing productivity (Pfeffer & Langton, 1993) . Management support in Malaysian public universities correlates with increased research engagement (Fauzi, 2023).

The Malaysian higher education landscape has transformed since the 1990s, notably in the public and private sectors. However, persistent gender stereotypes contribute to a notable imbalance among senior staff in public institutions. The private sector has seen slow progress in addressing this gender disparity over the past two decades (Jamil et al., 2019). A Malaysian private university ranked second nationally in the Times Higher Education Ranking 2021, which prompted an exploration of how academics in private institutions connect to Knowledge Sharing (KS) behavior and subsequent research engagement. In a Saudi Arabian public university, 39% of faculty acknowledged engagement in intra-institute research collaborations, but cultural identity emphasizing Islamic values hinders strong motivation for collaborative research with colleagues. As a result, faculty predominantly pursue individual research endeavors (Borg & Alshumaimeri, 2012). In Thailand, women are significantly represented in research across diverse sectors and fields. Within government, higher education institutes, public enterprises, and private nonprofit organizations, they constitute a majority, accounting for 54.2% of researchers. Meanwhile, in the industry sector, women still make up a substantial portion, comprising 47.5% of researchers (UNESCO, 2018). In Myanmar and the Philippines, women are the predominant proportion of science researchers compared to men, as shown in the figure below. Women hold 5.7 percent of the highest research positions (typically director of research or full professor) in Brunei Darussalam, where

representation of women decreases with seniority, which is in line with the global trend. Myanmar is the exception, where women hold 71.6 percent of the highest research positions (UNESCO, 2018)

FFigure 1: Gender Composition of Science Researchers



Source: UNESCO 2020

Brunei's government has prioritized science education, allocating sufficient resources across all schools. Despite well-equipped government schools, there is a concerning trend of declining enrolment in the science stream. Additionally, examination results suggest unsatisfactory outcomes, highlighting the need for further attention to enhance science education effectiveness (Khine, 2002) . Gender inequality in science education is evident in Bruneian textbooks. An analysis of textbook content reveals disparities in the representation of males and females in illustrations and text. This examination paints a picture of how science is portrayed, indicating the extent to which it is presented as a pursuit equally suitable for both boys and girls(Elgar, 2004).

IIn the Brunei civil service, women constitute about 50.4%, with a higher presence in Divisions II, III, and IV. Despite gender gaps in academic achievements favoring women, they remain underrepresented in senior-level civil service positions, where only one in five holds such a position. In STEM fields, female tertiary graduates in Brunei reached 49%, surpassing rates in Singapore and the United States between 2014-2016. However, historical trends show a preference for 'lower level, clerical jobs' among Bruneian women (Dhindsa, 2008) . In Myanmar, a notable gender disparity exists in leadership positions, predominantly filled by males. While there may be some women in senior roles, this presence does not equate to gender equality. Widespread inequalities persist, encompassing areas such as political representation, societal perceptions, gender stereotypes, and access to resources (Khin Khin Mr, 2021)

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While career advancement in Indonesian academia is theoretically nationally regulated to ensure equal opportunities, women in Islamic HEI (Higher Education Institutions) face disparities. They exhibit lower productivity in publications, hold lower academic ranks and leadership positions, and earn significantly less than their male counterparts. The suggestion is for these institutions to specifically empower women by supporting their continuing education, professional development, and career opportunities (Kholis, 2012)

In the UNDP's 2010 Human Development Index, Indonesia ranks 124th out of 187 countries, lower than Brunei (33) and Malaysia (61) but higher than the Philippines (112). Notably, Indonesia outperforms Vietnam (128) and India (134). Despite its overall ranking, Indonesia excels in expected years of schooling (13.2), surpassing most of these countries, except Brunei (14.1), and outperforming Malaysia (12.6) (Priyatna, 2013).

In a study of higher education institutions in Catbalogan City, Philippines, 30 participants shared their experiences through a validated questionnaire. The findings revealed that women respondents encountered gender biases in the workplace, particularly within the institution's regulations and procedures, despite government initiatives promoting gender equality (Irene Evangelista, 2017). In many higher education institutions in the Philippines, women mostly occupy middle and senior-level positions but are less represented in the highest-ranking positions (Morley, 2014). In traditional times in Thailand, the presence of a bilateral and matrilocal kinship system and the high work participation rates among women in the modern, rapidly globalizing economy were sometimes seen as indications of minimal gender discrimination. In the 1990s, the demand for women's studies programs emerged, with both successes and setbacks. Graduates from these programs became leaders and have since played crucial roles in defending women's rights. A notable divide exists in Thailand between the household, where women play pivotal roles in family sustenance, and the public political culture. In the latter, women's internationally renowned 'pleasing personality' is a crucial element in a complex structure that often reflects subservience (Tantiwiramanond, 2007). The 2007-2009 Thai Labor Force Surveys indicate that only one-third of employed STEM graduates work in STEM occupations. While STEM degree holders in STEM fields enjoy a 30% wage premium, those working in non-STEM fields experience only a 2% premium. This suggests that STEM education yields significant returns in STEM occupations but lower, or even negative, returns in non-STEM fields, particularly for women (Jessica Vechbanyongratana & J Vechbanyongratana, 2015) . The International Labour Organization (ILO) estimates that 44% of employment, equivalent to over 17 million jobs, is at risk of automation in Thailand. Women are disproportionately employed in jobs with low STEM skills, making them more susceptible to automation. They are 50% more likely than men to face job loss due to automation. In the industry, 85% of total

female labor holds low-skilled occupations. The ILO program aims to enhance women's acquisition of critical soft and technical STEM-related skills, addressing skills mismatches to boost productivity and enhance competitiveness in the evolving landscape(International Labour Organisation, 2020).

Table 2: Average Monthly Earnings of Employees in Professional, Scientific, and Technical Activities by gender (in US $)

Country	Year	Male	Female
Brunei Darussalam	2014	$2,214.31	$1,840.24
Cambodia	2019	$466.82	$375.74
Lao PDR	2017	$298.40	$203.14
Malaysia	2020	$1,110.27	$799.81
Philippines	2020	$544.08	$488.88
Singapore	2020	$4,769.73	$3,815.93
Thailand	2020	$780.76	$751.25
Vietnam	2021	$422.08	$371.81

Source: International Labour Organisation

Across the professional, scientific, and technical sectors, women generally hold lower representation than men, except Myanmar. There persists a significant gender pay gap. On average, women earn as little as 68 percent of what men earn in these sectors, highlighting substantial disparities in earnings based on gender. Women in STEM leadership across ASEAN are underrepresented but generally outperform global averages. In STEM policy roles, women are still underrepresented across all government levels. For example 2017, women constituted 35% of permanent staff positions in Lao PDR's Ministry of Science and Technology (G. A. Lemarchand, 2018). In Malaysia, women occupied 23.7% of board seats in life sciences and healthcare companies in 2021, surpassing the global average of 21.3%. In technology, media, and communications companies, women held 7.8% of board seats in Indonesia, 20% in Malaysia, and 22% in Singapore in the same year (Deloitte Global, 2022). Women are underrepresented in executive positions, with only 14% holding chief technology officer roles in Singapore and 12% in other ASEAN Member States (AMS). Additionally, companies are recruiting women from Asia-Pacific offices for global roles based elsewhere (Helen Coult, 2020)

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2.4 Barriers to women's participation in STEM institutions in Southeast Asia

Women encounter various barriers in pursuing, staying in, and progressing within STEM professions, ranging from personal and cultural hurdles to structural and systemic obstacles. These challenges lead to low representation of women in STEM fields. Women's active involvement in STEM careers, whether as entrepreneurs, employees, researchers, or leaders, is vital for fostering innovation and driving sustainable economic growth across the ASEAN region. (UNESCO, 2018)

Math achievement was connected with coping mechanisms, study strategies, learning styles, and self-efficacy in a study of Year 13 students in Brunei. Poor arithmetic performance prevents students of both sexes from enrolling in science and technology programs, which are essential to Brunei's industrialization. Particularly, fewer men than women are admitted to Higher Education Institutions (HEIs), which may be related to lower male achievement rates in GCE "A-level" mathematics. There are apparent differences in the ideals of Asian and Western societies. Asian communities encourage collectivism, which includes asking for help from peers, whereas Western cultures emphasize independence. In addition to motivation, socioeconomic situation impacts academic achievement in mathematics and other courses. This element is commonly mentioned in talks on educational outcomes (Mundia & Metussin, 2019).

A self-rating questionnaire survey involving 1281 first-year students across eight higher education institutions in Cambodia explored factors influencing their initial choice of science and engineering major. Findings indicate that individual factors, encompassing personal characteristics and attitude, had the most significant impact compared to family and high school factors (Kao Sovansophal & Kinya Shimizu, 2019). Intrinsic motivation, notably, is a crucial factor empowering academics to excel in their research pursuits (Snowball & Shackleton, 2018).

Women are more likely to major in STEM and computer technology outside the capital in Cambodia. Markers of urbanization and socioeconomic development largely predict women's participation in health and IT majors. It is interesting to note that there is a negative correlation in these industries between gender equality traits and women's representation (Perez-Felkner et al., 2020).

Female students' enrollment in science classes fell precipitously from 97% to 42% in Cambodian upper secondary schools between 2014 and 2019, whereas their enrollment in social science programs rose from 4% to 58%. The easiness of national exams, high passing rates, pursuing grades, attitudes toward science, and the cost of private tuition were all significant influencing variables. Female students stated they had no intention of pursuing STEM degrees, frequently due to family disapproval of science-related fields. (Pov, 2023). Social Cognition Career Theory (SCCT), which was developed from Albert Bandura's social cognitive theory, was deemed the most relevant framework for analyzing the situation of women in STEM in Cambodia. It looks at how societal influences, gender, cultural norms, genetic characteristics,

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and unforeseen life events can affect one's career choice. It also highlights how an individual's job decisions are shaped by the interaction of their self-efficacy, outcome expectations, and personal aspirations. (Monyrath Sar, 2021).

Deeply rooted social conventions, religion, and culture all play a part in Myanmar's widespread inequality. The heritage of patriarchy and authoritarianism sustains the acceptance of women as a secondary gender. Women's equality is limited in this country due to the macho state and male-dominated institutions; national participation in upper and lower houses is less than 14% (Khin Khin Mr, 2021). In Myanmar, women's and girls' job advancement is impeded by institutional restrictions. Elevated academic barriers, especially in fields like engineering and medicine, disproportionately benefit men, restricting girls' educational opportunities and violating their human rights. This framework prevents women from achieving leadership positions, perpetuating gender inequality (Ei Yin Yin Phyu, 2023).

While there was initial progress, Myanmar's existing political and socio-economic challenges demand extra research and dedicated efforts to promote quality education and establish gender justice. The term "culture" in Indonesia has to consider the complexity brought about by several religions, especially Islam, which is the predominant religion and cannot be limited to the varied local ethnic groups. In this environment, the concept of "local culture" becomes complex. In Indonesia, women who want to go to college must negotiate several public spaces in addition to intricate cultural and religious norms. It might be not easy to juggle responsibilities as workers, instructors, spouses, mothers, and students. These women must manage a complex network of social, cultural, and familial roles, reflected in their juggling these varied responsibilities. (Priyatna, 2013) . Even though gender equality is becoming more widely acknowledged in Indonesia, women in postsecondary education face obstacles in pursuing senior leadership roles. The leading causes of obstacles are not institutional barriers but family obligations, patriarchal cultural norms, and inadequate assistance (Dini Cahyati et al., 2021).

Female scientists from Western Europe and North America said Singapore had a less family-friendly work environment in qualitative research with STEM professionals. On the other hand, Asian participants mentioned that they could focus more effectively on their scientific careers if they had domestic servants. Male secondary students in Singapore showed a predisposition for engineering and mathematics programs, while female students tended to gravitate toward the arts, social sciences, and medicine. Students who identified as female were more inclined to think that their skills were necessary. Males preferred engineering in junior college, while females selected the arts and social sciences. The latter group's choice was influenced by professional goals and parental guidance (Teo & Yeo, 2017).

According to a case study on women's careers in agricultural science in the Philippines, women who have two jobs have more significant difficulties than males. Delays in training, moves brought about by husbands' jobs, and restricted mobility are some of the restrictions. Gender roles continue to be

stereotyped in culture, which affects interactions at work and prevents women from rising to top positions. Cultural obstacles remain the principal obstacle preventing women from advancing in their careers, even in emerging countries where the number of women working in research institutions is rising (Brush et al., 1995) . According to a study conducted on 4967 junior high school students in Vietnam, gender has no bearing on academic success in STEM fields. Still, female kids did better when their parents worked in non-manual jobs than male students. Improved study scores were connected with non-manual jobs, higher parental education, and better economic standing. On the other hand, poorer academic achievement was linked to having 0 or more siblings. These results highlight the significance of preserving family size and giving women access to education to guarantee fair resource allocation for children (Ho et al., 2020). In a qualitative study that included 21 participants in a Vietnamese university, the women leaders were inspired to progress in their careers by ongoing support from family and mentors, shifting employer perceptions, and their proven leadership abilities. (Maheshwari & Nayak, 2022).

In the Lao PDR, economic priorities and educational goals sometimes collide, especially in underprivileged areas where kids must help support the family. Primary education quality, the competency of teachers and principals, the absence of learning resources, multi-grade teaching, and a poor pedagogical support system are among the issues that need to be addressed. These limitations greatly influence how girls and women will participate in STEM education in the future, both in their career trajectories and at higher levels (Niane Sivongxay et al., n.d.) Improving the quality of life for women in Timor-Leste requires meeting their fundamental requirements, which include access to primary education, health care, food, clothes, and shelter. These needs are frequently the focus of traditional aid. To overcome women's adverse conditions relative to males, it is equally vital to fulfill their strategic demands. These strategic needs include political voice, education, freedom from violence, access to personal income and a means of subsistence, and support for early childhood care. Women now confront several obstacles, such as pervasive poverty, a high rate of spousal abuse, and a lack of recognition for their contributions to the political, economic, and social spheres (H Hill, 2012).

3. Efforts made to support Women's Participation in STEM institutions in Southeast Asia

Table 3: Programmes to Improve the participation of Women in STEM in Southeast Asia

Country	Programme	Description
Indonesia	SheHacks	Indosat Ooredoo Hutchison's SheHacks program in Indonesia aims to empower

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		women and girls in technology. Since its 2020 launch, the program has empowered over 1,500 women and expanded in 2022 to include mentoring, incubators, and boot camps.
Myanmar	Geek Girls Myanmar	The organization empowers women in the ICT industry, enhancing their tech access and narrowing the gender digital gap. It offers tea talks, roundtables, webinars, and workshops covering leadership, female entrepreneurship, cyberbullying, digital literacy, and more. Additionally, it fosters an online community for women and girls to share tech knowledge.
Thailand	STEM Training Program	In 2019, the Ministry of Labor, ILO, and UNESCO collaborated to develop a STEM training program for entry-level women workers in the electronics sector. This enhanced data collection, analysis, and presentation skills for informed decision-making. It served as a pilot for a UNESCO global STEM policy toolkit aimed at addressing gender disparities and improving evidence-based policy in STEM.
Brunei Darussalam	Women in Science Competition	Seria Energy Lab's competition, launched in 2019, crowns a young woman (age 13–17) in science. It aims to empower Brunei Darussalam's young women to tackle global challenges and improve their leadership, project management, and innovation skills.
Vietnam	SHINE:	12-week incubation program for early-stage

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		startup women founders by Ascend Vietnam Ventures.
Lao PDR	ADB's SSHEP II Project	It was enhancing higher education and vocational training for job-ready skills. Through grants and loans, it boosted women's leadership, educator expertise, and STEM enrollment.
Malaysia	IEM's Women Engineers Section	Uniting women in engineering across Malaysia with six chapters.
Philippines	Women: Innovating Social Enterprises (WHWise) Program	Philippine Council for Industry, Energy, and Emerging Technology Research and Development's (PCIEERD) WHWise Program supports women-owned social enterprises with technology access, funding up to Php 5 million, incubation, mentoring, and research assistance.

3. Intervention by the United Nations for the promotion of women in STEM fields

The United Nations is a central hub for dialogue and cooperation, facilitating collective solutions. Strong member state support provides a clear roadmap towards a shared goal addressing global challenges and caring for our typical global home.

On September 25, 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, succeeding the Millennium Development Goals (MDGs) as the global framework for international development. The Sustainable Development Goals to increase the participation of women in STEM are Goal 5, i.e., Achieve Gender equality and empower all women and girls, and Goal 10, i.e., Reduce inequality within and among countries. Goal 5 talks about the significant legal and legislative reforms essential to safeguard women's rights worldwide. Despite some progress, there remains a global gender wage gap, with women earning, on average, 24% less than men in the labor market. UN Women supports women in obtaining quality employment, acquiring assets, and exerting influence on institutions and public policies. It emphasizes the importance of acknowledging, reducing, and redistributing the

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burden of unpaid care. Goal 10 talks about how the wage gap varies between countries, with women earning 24% less than men. Additionally, they are also more prone to vulnerable employment, with up to 75% of women's jobs being informal or lacking protection in developing countries (United Nations, n.d.) Globally, 83% of domestic workers are women, and the majority lack legal entitlement to a minimum wage. Gender discrimination can intersect with other forms of discrimination, including age, disability, ethnicity, and economic status, compounding the burden of inequalities. UN Women actively addresses inequality within and among countries by advocating for decent work, social protection, and gender-sensitive economic policies globally. This includes eliminating discriminatory laws and practices and promoting appropriate legislation, policies, and actions. It advocates for employment policies that enhance labor market conditions and promote decent work for women, along with ensuring the safe migration and social protection of domestic workers (UN Women, 2013)

The aims and role of UNESCO for the promotion of women in STEM include enhancing the participation, achievement, and continuity of girls and women in STEM education and careers to narrow the gender gap in STEM professions, building the capacity of countries to provide gender-responsive STEM education, focusing on teacher training, educational content, and pedagogy, raising awareness about the significance of STEM education for girls and women (*International Day of Women and Girls in Science*, 2018). The UNESCO Engineering Initiative (UEI) focuses on increasing enrolment in engineering programs at the tertiary level to sustain and enhance socio-economic development, thereby encouraging and inspiring the youth to address contemporary challenges and ensure an adequate supply of engineers for future sustainable development. UEI provides a platform for youth to express their views on current engineering and development issues through events like the UNESCO Youth Forum and World Science Day 2013. Some more initiatives include the 8th UNESCO Youth Forum, World Science Day 2013, World Teachers' Day 2013, Engineering Outreach Event in Nigeria, and Airbus: Fly Your Ideas(United Nations, 2021).

STEM and Gender Advancement (SAGA) is a Global UNESCO project supported by Sida to reduce the gender gap in STEM across education and research levels. It identifies and addresses gaps in policy related to gender in science, technology, and innovation (STI) based on evidence, enhances capacity for data collection on gender in STEM fields, increases visibility, participation, and respect for women in STEM, improves tools for measuring the status of women and girls in science (UNESCO, 2015).

Women in Science Report (UIS) data reveals that women comprise less than 30% of the world's researchers. The data also provides insights into the distribution of these women across public, private, and academic sectors, as well as their respective fields of research (UNESCO Institute for Statistics, 2019)

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Under L'Oréal-UNESCO For Women in Science, UNESCO and the L'Oréal Corporate Foundation aim to honor women researchers who have significantly contributed to addressing global challenges. By recognizing their work in areas such as new technologies, aging populations, and biodiversity threats, UNESCO and L'Oréal aim to acknowledge and support these women researchers, enabling them to continue their impactful contributions to science (UNESCO, n.d.-a)

The World Federation of Engineering Organizations (WFEO), established in 1968 under UNESCO, unites national engineering institutions from around 100 nations, representing over 30 million engineers. Its mission is to enhance engineering practice and advance the UN Sustainable Development Goals. The Paris Declaration (March 2018) reaffirms engineers' commitment to sustainable development, fostering socio-economic security, sustainable development, and global poverty alleviation through the proper application of technology. (UNESCO, 1968). The WEF Future of Jobs Report aims to analyze and offer detailed insights into the extent of emerging trends by industry and geography. It focuses on the expected timeframe for these trends to impact job functions, employment levels, and required skills (World Economic Forum, 2023).

The Organization for Women in Science for the Developing World is an international organization (program unit of UNESCO) offering research training, career development, and networking opportunities for women scientists in the developing world at various career stages (UNESCO, n.d.-b)

4. Recommendations

Legislation plays a crucial role in establishing an equitable and equal workplace. Government policies effectively address the representation and rights of disadvantaged groups, fostering a fair and inclusive work environment. Schemes and measures should aim to mitigate disruptions and support the continuity of careers. Sensitization efforts should prioritize facilitating the return of women to the field of science after career breaks. There is a need to change the mindset of administrators and colleagues. Child-care gaps reflect a systemic bias against women's employment globally, and efforts need to be made to provide for child care at the workplace. This issue persists mainly in Western countries, hindering women's career paths as women in institutes face challenges balancing work and childcare due to the lack of support. Re-entering the profession is also hindered by age-based restrictions. The goal is to create workplaces that eliminate the need for career breaks. Institutions should actively recognize and reward excellence women demonstrate as more women will be encouraged to pursue STEM careers. Women may endure unacceptable behavior due to fear of potential repercussions. The most extreme form of social exclusion is sexual harassment. There is a need to underscore the importance of addressing such concerns promptly and thoughtfully. Sexual harassment encompasses instances where male scientists seek sexual favors from

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their juniors, along with various forms of verbal and other abusive behavior. Implementing effective measures for addressing and preventing harassment issues is the need of the hour. In this regard, gender sensitization programs for male and female scientists in major R&D institutes are facilitated by organizations such as UGC, CSIR, IAIR, ICMR, etc. Another concern is lack of proper transportation and safety, leading to lower stay-backs for work and informal interactions necessary for collaborations. Women are eight times more likely to reach leadership or supervisory positions if the organizational form of networking exists as opposed to hierarchy or bureaucracy in other disciplines. (Smith-Doerr, 2004) . Informal interactions between male and female researchers are crucial for dismantling organizational hierarchies and fostering a socio-cultural environment conducive to fruitful research. Inspiration from seeing other women at the top in science fields inspires the ones in the lower positions too to achieve success. (Blaszczak et al., 2022) . Because of the trickle-down effect of few role models for women engineering students, there is a dearth of academic women engineers in visible leadership positions responsible for the under-representation of women engineers in academia, industry and government. Encouraging women faculty to consider formal leadership positions and providing structured opportunities to explore those options will likely result in faculty members participating as academic leaders. (O'Bannon et al., 2010). Family, gender ideology, and HR organizational practices determine the employment relationship and can help women in S&T to grow in their careers. (Valk et al., 2014). Apart from the support from spouses and encouragement from peers, the workplace environment has to be more supportive of the needs of women, fewer differences remaining in interpersonal communication, and the adoption of specific strategies by women to work effectively in male-dominated organizations would be helpful (Boiarsky et al., 1995). Family-friendly policies and organizational norms help women progress in their careers, whereas toxic work environments and societal issues inhibit the growth of women in the business sector. (Nabila Khurshid1, 2022) . Female scientist's productivity is not only positively influenced by intrinsic factors like self-motivation and confidence, but extrinsic institutional factors such as flexible working hours, woman-oriented management policies, fair appraisal, and mentorship also play an essential role (Fathima et al., 2020). Patriarchal norms restricting women's mobility hinder their effectiveness in career-related tasks and advocacy for career advancements. These barriers limit women's engagement in the public arena, impacting their roles as scientists. To avoid discrimination in grant funding because of certain stereotypes of women being incapable of doing science, grants should be awarded based solely on the merit of proposals.

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5. Conclusion

Llimited research exists on barriers women face in STEM leadership roles, especially in Southeast Asian nations, despite extensive studies on women in leadership and STEM separately. The disparity in understanding the unique challenges women face in STEM leadership in these nations presents a significant barrier to advancing female participation and progression in STEM fields. It is imperative to explore these obstacles comprehensively, considering their potential impact on gender equity. Persistent barriers such as work-life balance struggles, gender bias, and microaggressions underscore the necessity for targeted research in this area. Support from individuals championing gender equality is crucial in enabling women to persist and advance in STEM leadership roles. Achieving gender equity requires a cultural transformation within STEM and leadership domains, fostering environments where women's achievements are valued and their authority is respected. There is a dire need to improve the chilly climate for women in STEM. This means revising institutional cultures to be more inclusive, creating educational environments that support and validate women's contributions, and implementing policies that promote equal treatment and support for women scientists, particularly from disadvantaged backgrounds. Addressing inequality in STEM participation necessitates educational and awareness programs, scholarship incentives, and flexible career policies to support women's advancement. Ensuring R&D institutes provide essential facilities for women scientists, including appropriate toilets and transportation during odd hours, similar to provisions in call centers. They are encouraging professionals to realize their full potential, guiding them to available support, and promoting a professional approach to careers. Raising awareness about societal and institutional structures that facilitate successful navigation of family and career dynamics and promoting awareness and sensitivity across society and institutions regarding the challenges women face in successful participation in science.

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University Social Responsibility of Higher Educational Institutions in the Global South: A Case of Indian Academia

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Abstract

This study investigates higher education institutions' diverse social responsibility initiatives and assesses their impact on stakeholders (present students, future students, supporters, etc). Social responsibility emphasizes contributions to sustainable development and proactive solutions to societal and environmental challenges. Recognizing universities as crucial pillars of society, this research explores how they foster socially responsible values in students to cultivate responsible citizenship, focusing on the next generation of leaders. Data was collected using semi-structured interviews from 103 heads of STEM (Science, Technology, Engineering, Mathematics) departments in twenty engineering colleges in Delhi, India. A thematic content analysis using QDA Miner Lite software (ProvalisResearch) had been used to analyze the data. The results were organised into three categories:
The study explores students' involvement in USR activities, implementation challenges, collaborations with corporations, NGOs, and universities, and energy-saving initiatives for sustainable campuses. It emphasizes promoting diverse student experiences, community engagement, and fostering professional and socially responsible development and provides recommendations for stakeholders to achieve environmental sustainability.

Keywords: USR (University Social Responsibility), HEI (Higher Education Institutions), CE (Community Engagement), Sustainability

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Introduction

University Social Responsibility (USR) is the ability of higher education institutions (HEIs) to promote and apply a set of principles and values in management, teaching, research, and extension to address educational and social challenges in society (Meikle, 2023). In the current globalized and competitive environment marked by economic crises, there is a critical need to explore new sources for economic and social growth and development Social responsibility is an ethical framework signifying an entity's obligation, whether an organization or individual, to act for the overall benefit of society. It involves maintaining a balance between the economy and ecosystems (Vasilescu et al., 2010). In this context, both individuals and organizations need to contribute to society and the environment. Recognizing that revenue is derived from these sources, it becomes a fundamental duty to give back. The United Nations established 17 Sustainable Development Goals (SDGs) as a global initiative for all countries to address climate change, eradicate poverty, and foster sustainability by 2030 [1]. Higher education is essential in achieving these goals, as universities play a pivotal role in generating knowledge and nurturing talent. The success of the SDGs relies heavily on significant contributions from university education and research. Higher education institutions, particularly universities, increasingly view social responsibility as an integral aspect of their mission [2]. They bear the responsibility of ensuring that academic knowledge directly contributes to improving human living conditions and the development of civil society. So, they should focus on cultivating future leaders capable of initiating social change, transforming innovative ideas into practical steps for a more inclusive and sustainable future. [3]

Community Engagement (CE) is the higher education institution's counterpart to Corporate Social Responsibility (CSR). While teaching and research were traditionally considered core functions, CE is now widely accepted as the third core function. CE enables universities to leverage their expertise to meaningfully address the development challenges of their communities and country. Community engagement is vital in higher education, equipping students for the workforce and instilling a sense of civic responsibility. It involves students engaging in conversations with communities and institutions to comprehend the lived experiences of their partners. This involvement enables Higher Education Institutions (HEIs) to have a tangible and positive impact on society at large (Driscoll, 2009).

Rapid industrialization, modernization, urban migration and population growth have incessantly depleted the non-renewable resources, resulting in scarcity. The exponential demand for limited resources has increased costs, exacerbating their scarcity. In the current globalized and competitive environment marked by economic crisis, there is a critical need to explore new economic and social growth and development sources. In this context, individuals and organizations need to contribute to society and the environment. The United Nations established 17 Sustainable Development Goals (SDGs) as a global initiative for all countries to address climate change, eradicate poverty, and foster sustainability by 2030. Science, technology, and engineering are vital to the achievement of these SDG, and engineers have changed the world, starting from the development of tools from stones to artificial intelligence and big data; they are needed in every sphere of society.(Velazquez et al., 1999).Higher education in technical disciplines is also essential in achieving these goals, and universities play a pivotal role in generating knowledge and nurturing talents. The success of the SDGs relies heavily on significant contributions from university education and research. Higher education institutions, particularly universities, consider social responsibility an integral part of their mission (Vasilescu et al., 2010). They are responsible for ensuring that academic knowledge directly contributes to improving human living conditions and the development of civil society. So, they should focus on cultivating future leaders capable of initiating social change and transforming innovative ideas into practical steps for a more inclusive and sustainable future. (Ostrander, 2004).

Currently, research on different types of USR initiatives and the challenges faced by universities in developing nations is limited,. This study tries to fill this gap by shedding light on the experiences of the heads of departments of various engineering colleges in Delhi, India. Further, it also gives

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recommendations for the universities. The study includes the STEM leaders of only engineering colleges because technical disciplines are high in demand for innovation, and global warming is a cause of concern for the world. In this regard, green innovation management will help the university students (future entrepreneurs) adopt sustainable practices while innovating, which can reduce the negative environmental and economic impact. It now serves as a vital catalyst for national and regional economic growth, playing a pivotal role in fostering sustainable development (Wang et al., 2021).

Theoretical Background

There needs to be more literature specifically addressing social responsibility in higher education from Africa, excluding South Africa, as well as in Asia and the Middle East. Generally, the social responsibility literature complements the extensive body of work on community engagement. It offers insights into how social responsibility is manifested within Higher Education Institutions (HEIs) and their collaborations with communities and society. In a study of engineers in an HEI, which tried to analyze the student's contribution to society, it was analyzed that the inclusion of a course on sustainable development in the engineering curricula could motivate the students to contribute to society. (Pritchard and Baillie, 2006). Engineering students must know the interaction between society, technology, and the environment so that the benefits of technology are positive for all. (Installs, 1996). In a study by an Australian university, the results revealed that to achieve sustainability and have a good quality of life, engineers need to create or modify existing technologies to enhance efficiency. For, e.g., they can develop technologies for the poor and the desolate to upgrade them in society and help them come out from the shackles of poverty. (Johnston, 2001) According to the world data, 12% of the population did not have electricity in their homes in 2016; in 2015, 2.1 billion people did not have access to safe drinking water. To address these challenges, the economic, social, human, and environmental impacts of engineering need to be considered. Courses that help engineers incorporate such value-based perspectives need to be added to the engineering curricula of educational institutions. (UNESCO, 2021) . To make engineers sensitive to the demands of the global world, they need to be educated in courses like ethics and environment (Johnston, 2001). Courses like STS (Science, Technology, and Society) have been developed to educate engineers and make them understand how their contributions can benefit society's welfare.

A study on Malaysian university students revealed that most were aware of the importance of environmental preservation but lacked exposure to actual social responsibility activities (Ahmad, 2012). In a study of Ethiopian HEIs, the USR activities were present, but the significant impediments were a lack of precise institutional arrangements, limited funding, inadequate collaboration/partnerships, lack of comprehensive data, and insufficient emphasis on morals, ethics, values, and principles (Cremonini and Adamu, 2021). In another study carried out in the US, the results revealed that a collaboration between the government and the undergraduate students of a university on a sustainability project benefitted the government agency and the students. With collaborations, the students gain hands-on experience and also achieve recognition through the presentation of papers at conferences.(Elaine Venson; Rejane Figueiredo; Wander Silva; Luiz C. M. Ribeiro, 2016). Recruiting students in firms as interns serves as a route for interaction between firms and universities.(Thune, 2009). Informal contacts, conferences and publications, consultancy, and recruitment from college were the factors that led to university-firm tech transfer. Education by a university on conducting sustainable research for its students is an important factor in determining the economic development of a country. (Veugelers, 2016).

Methodology

The aim of the study was to discuss the USR activities undertaken under the STEM leaders in different ways and how they can help to transform society in social and economic ways. The study utilized a qualitative explorative design rooted in hermeneutic phenomenology to gather descriptive data on the opinions and experiences of STEM leaders with USR activities in various departments of engineering colleges in Delhi, India. Interpretative phenomenological analysis emphasizes on providing detailed

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accounts of experiences in participants' own terms, avoiding predefined categories. IPA is considered phenomenological, focusing on interpretation, with a hermeneutic commitment to understanding (Smith and Fieldsend, 2021) . Data had been collected using semi-structured interviews with 103 Heads of departments of STEM (Science, technology, Engineering, Mathematics) disciplines, and thematic analysis has been conducted using QDA Miner Lite software (Provalis-Research). A census was done and emails were sent to all the HoDs to give their nod to personal interview sessions where out of 127 STEM HoD's in a total of 20 engineering colleges of Delhi providing regular Btech degrees, a total of 47 agreed to give personal face-to-face interviews in the first round and 56 in the second round. So, a total of 103 leaders were involved, and their experiences with USR activities are the focus of this study. The interviews were conducted for a period of eight months in the respective departments of HEI's, starting from 01-10-2022 to 31-05-2023. An institutional approval letter was shown to the respondents to get their consent and they were informed that the results would be anonymised. The respondents included heads of the following ranks i.e, professor and associate professor. Open-ended questions were posed during interviews lasting an average of 20 to 30 minutes. While flexible, all respondents were asked a similar set of questions. The Consolidated Criteria for Reporting Qualitative Research, (COREQ) was completed (Tong et al., 2007) (Appendix A). The first author conducted the interviews and no other individual was present in the interviews. Coding was done by both the authors. Both the authors had no prior relationships with the majority of research participants. However, the first author had met one participant at a conference. Research participants had received information sheets explaining the study's purpose without personal details about researchers. While participants knew the researchers' identities through email correspondence and could access their research interests online, this might have influenced their responses during interviews.

The thematic analysis approach (Braun and Clarke, 2023) was followed and it ensured that research findings were rooted in the understandings and experiences of respondents, reflecting their subjective meaning. Interviews were recorded, and data was coded and transcribed verbatim. The transcribed data were collected using The Framework Method (Hackett and Strickland, 2019) and then analyzed thematically using coding process (Braun and Clarke, 2023). Data were initially organized into an Excel spreadsheet using a framework matrix. Each investigator coded the data. The thematic analysis involved constant data checking, and meetings to review and combine themes. The process focused on inductively identifying emerging themes rather than a hypothesis-deductive approach. After extracting the ideas, the coding had been carried out in three phases.

Interview guide:

Q1 What are the types of USR activities that your department is involved in?
Q2 Do you face any challenges from the university about its operations?
Q3 Are there any linkages to develop the required skills among the students?
Q4 How do you inculcate the value of economic, social, or environmental responsibility among students, or can you provide any suggestions?

Population	*Public*	*Private*	*Total*
Heads of Science	Male - 40, Female- 26, Total- 66	Male - 25, Female - 12, Total- 37	Male - 25, Female - 12, Total- 37
Heads of Engineering	Male - 25, Female - 12, Total- 37	Male - 25, Female - 12, Total- 37	Male - 25, Female - 12, Total- 37

Note: Applied science, i.e., Physics, Chemistry, Mathematics, and Engineering branches: IT/Electronics/Mechanical/Biological Sciences/Civil/Design/Environmental/Architecture/Material Sciences/Energy Sciences/Textile and fiber.

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Source: Prepared by the authors

Table 1: Information of the respondents:

Population	Public college	Private college	Total
Heads of departments Professor – 92 (38 to 59 yrs) Associate Professor – 11 (36 to 45 yrs)	Male - 40, Female - 24, Total- 68	Male - 25 , Female - 14, Total- 38	Male - 65, Female – 38, Total- 103
All Engineering disciplines	Applied science (Physics, chemistry, maths), IT, Electronics, mechanical/biological sciences, civil/design/environmental engineering, architecture and planning, material sciences, energy sciences, textile and fibre.		12

Source: Made by the authors

Results

The qualitative data after coding has been categorized into the following themes:

Theme 1: Involvement in economic, social, and environmental activities

The qualitative data from respondents' interviews showed that in many departments of various universities, the USR activities were absent, or the Heads of the departments didn't take the initiative to conduct these activities, and only a few outreach programs were done to meet the institutional requirements. The average no. of projects ranged from 2-3 in a year. The universities that were engaged in USR activities had diverse perspectives. When asked about the type of USR activity their department is involved in, they were engaged in three types of activities: economic, social, and environmental. For e.g., Projects like Education for all, gender sensitization, mental health awareness, design for the marginalized, inclusive design, design for all, etc. Many were involved in social activities like woollen clothes distribution, blood donation, health camps, renewable energy, campaigns for saving water and electricity, plantation, anti-drug camps, cleanliness drive, voter's awareness, programs like adopt five villages nearby colleges, medicines to needy people, sleep awareness program for patients, education mentoring of govt. School girls in STEM, donation to Kerala relief fund, several projects done by the students targeting the benefit of the rural areas.

Some excerpts from the interviews are provided below.

P 8: "We address most of UN SDGs, particularly SDG 7, SDG 13, SDG 4, e.g.: nutrition application, etc."

P 69: " There are solar panels installed, and rainwater harvesting is also there in the university." Yes, we have 146 kW Solar energy rooftop in my college."

P 60: "Many of the faculty members in our department are working in the area of solar cell technology, green technology, sensors, cancer research, and targeted drug delivery."

P 83: "The faculty members are setting up the waste treatment plant."

P 72: "Some of my students work in corporate hospitals and provide free healthcare services to the poor every Friday afternoon, and they thank me for motivating them for this, and it is giving them more happiness than their salary."

P 2: "Our students participated in SAGY (Saansad Adarsh Gram Yojana) in a nearby village as a part of the NSS activity. They are also mentoring poor students and giving them free tuition".

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P 81: “We are working on making the university zero waste. I have worked on composting kitchen waste to produce manure, refurbished furniture, and reduced condemnation. Reused and recycled civil and paper waste”.
P 44: “Students have been involved in tree planting, park cleaning, waste recycling, training workshops, university fairs, etc..”
P 27: “Our students participate in many volunteering programs. They collaborate with NGOs for community outreach. I feel that such initiatives empower them with a sense of social responsibility and help foster an understanding of all the challenges of the society”.
P 91: “Under community services (CS), students actively engage in programs, volunteering in various homeless shelters, low-income schools, family support centers etc. The university also emphasizes providing students with different opportunities to bring about positive change in the local communities.”

Sub Theme 1.1: Energy saving initiatives taken by universities

The participants had informed about the projects undertaken by their institutions and further information had been verified from the websites. DTU announced the upcoming installation of a 432-kW solar power plant, set to be installed on rooftops and covering an area of 7050 square meters (Mohammad Ibra, 2019). HMR Institute of Technology & Management is a prominent private engineering college in New Delhi, India. It offers a range of courses in both engineering and management disciplines. In pursuit of a green vision, HMR Institute of Technology & Management partnered with Tata Power Solar to install a 146-kW rooftop system. The institute now operates entirely on green energy, meeting 100% of its energy needs through solar power. Additionally, students are actively involved in hands-on learning through access to live solar projects, fostering awareness and expertise in green technologies. The rooftop solar system at HMR Institute of Technology & Management generates 204,000 units of electricity annually. Over 25 years, it is expected to offset 3,679 tonnes of carbon emissions (Tata Power Solar, n.d.)
Colleges under IP University have taken measures for energy conservation and usage of renewable energy to minimize the carbon footprint of the campus by leveraging solar power for electricity generation, implementing a biogas facility for renewable energy production, engaging in grid wheeling to optimize energy distribution, utilizing sensors for efficient energy conservation, incorporating LED bulbs and power-efficient equipment for reduced energy consumption, etc. Some more initiatives by the university in this regard include sustainable design with open courtyards, fly ash brick construction for energy efficiency, and energy-efficient screw chillers for air conditioning. LED luminaries, green reflect SOL glass windows, and clay-tiled surfaces enhance energy conservation. They also have provision for under-deck insulation, which reduces heating and air conditioning loads. A 140KW solar power plant generates 300,000 units annually, with surplus power fed into the grid. Solar water heaters are installed in four hostels, which provide 40,000 liters of warm water. Sensor-based electrical fittings are in key areas to minimize power consumption. Additionally, a biogas plant has been installed, which serves both lighting and educational purposes, emphasizing bio-resource recycling and societal needs (Guru Gobind Singh Indraprastha University, n.d.)
The Green Policy at IIIT-Delhi Campus includes Yule e-bikes to reduce conventional fuel vehicular traffic, building orientation, and window design is there for maximum natural light utilization, steps to reduce air conditioning load are being taken, terrace and walls are equipped with insulation, dry cladding, and cavity walls are there to minimize the solar radiation, there is waste segregation into biodegradable, non-biodegradable, and e-waste, on-site composting and disposal through authorized agencies is available, biomedical waste from the health centre and labs are responsibly managed by the authorized agency (M/s Biotics) under DPCC, i.e., Delhi Pollution Control Committee (Indraprastha Institute of Information Technology, n.d.)
MAC INSERCH is a collective initiative at Maharaja Agrasen College, uniting students, teachers, and administrative staff in their shared commitment to environmental conservation, heritage preservation, and overall sustainable development. The initiatives include five functional rainwater harvesting pits, a 10,000-liter Effluent Treatment Plant that manages water discharge from washrooms, the canteen, and the

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girl's hostel. Energy-efficient measures include hermetically sealed windows and cavity-walled structures in air-conditioned rooms. In many areas, LED lights are used instead of CFL and mercury tube lights. The Cycling Club Cyclopaedia also encourages eco-friendly commuting with 20 practice cycles and over 12 high-end bicycles (Maharaja Agrasen College, 2022)

MSIT has transitioned from incandescent bulbs to LED lights, replaced CRT monitors with energy-efficient TFT or LCD monitors, and advocates for efficient electrical systems. Regular maintenance of UPS batteries reduces charging current. There are frequent equipment checks which prevent excess electricity usage. The institute promotes energy conservation by urging staff and students to turn off fans and lights when they are not in use. Solar heaters in hostels reduce electrical power usage. There are transparent glass windows that bring natural light to classrooms. There will be a provision for solar-based LEDs on campus. The institution also adopts rainwater harvesting, where water is collected from an open terrace and then directed to the ground through drains to sustain groundwater availability. Efforts for Carbon Neutrality include No burning of leaves or waste papers, leaves buried in soil; there is waste disposal in Nagar Nigam dumping yards, minimal AC usage, routine inspections for lower emissions, a vast tree cover neutralizes the carbon in the campus (Maharaja Surajmal Institute of Technology, 2019). In NSUT's electrical engineering department, a dedicated renewable energy lab will cater to Simulation-in-the-loop setups, Real-time simulators, DC microgrids, Wind energy emulators, and Fuel cell setups.

IIT Delhi has a supercomputer, i.e., Padum, which was inaugurated in 2015 and employs chilled water-cooling technology and innovative energy-saving measures, earning it a "green" designation. It ranked 28th on the Green 500 list of the world's most energy-efficient supercomputers. The ESPOB (Energy Storage Platform on Batteries Centre) is researching various energy storage technologies, including flow batteries, supercapacitors, fuel cells, electrolyzers, Li-ion, Na-ion, Mg-ion, Al-ion batteries, and Li Recovery. A 50 kg/day capacity pilot-scale reactor has been designed and is installed at the IIT Delhi campus to address the electronic and plastic waste streams (IIT Delhi, 2013)

IGDTU has installed solar water heaters in hostels and guest houses so that students and residents can use green and renewable energy. There are energy-efficient lights campus-wide, and five percent of the energy demand is being met by solar panels via Hero Future Energies Pt. Ltd. The campus also has carton boxes for segregating paper and plastic collection and also promotes the recycling of litter (Indira Gandhi Delhi Technological University, 2012)

GB Pant Institute of Technology had installed rooftop solar panels to harness solar energy, generate electricity, and reduce operating costs (G.B Pant Institute of Technology, n.d.).

The new building of Vivekananda College features a rainwater harvesting system that stores water for gardening and running tracks. PM2.5 aerosol concentrations are monitored using standardized equipment from the CSIR-National Physical Laboratory. The college promotes cleanliness through waste separation campaigns and provides green and blue dustbins throughout the campus. Organic waste is composted using compost pits and a compost machine. Medical and electronic waste are managed separately, with designated bins and storage areas. Laboratories handle non-hazardous materials, reducing the need for exceptional waste management. The well-ventilated classrooms minimize energy use and are aided by natural lighting and cross-ventilation. Solar panels and LED lights further reduce energy consumption. Garden waste is composted, and burning is prohibited. RO plants ensure safe drinking water, while a greenhouse supports plant replication and maintains greenery. Soundproof generators provide efficient backup power near Gate no. 2 (Vivekanada College, n.d.). HMR Institute of Technology and Management is now the first green and energy-efficient institute in GGSIPU after installing a 146 KW grid interactive solar power plant (HMRITM, n.d.).

Theme 2: Collaborations with the stakeholders

Most of the participants had a limited view of USR, and they focussed only on the social dimension of it, whereas a few of the college heads had their students involved in the CSR activities through partnerships/collabs and had linkages with the industry (Microsoft, IBM, pharmaceutical companies, coding blocks) via MoU's and NGOs to conduct joint research projects. The respondents mentioned how

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training and placement cell helped sign MOUs to develop linkages with industries and how working with industry gave their students unique perspectives and an understanding of dynamic sustainability challenges and opportunities. Some excerpts from the interview are as follows:
P 22: "LinkedIn is a valuable platform for connecting professionals from various fields and bridging the gap between Industry and academia. Our students exchange ideas, insights, and experiences related to sustainable practices in the supply chain. I think it is important for students to learn socially responsible entrepreneurship".
P46: "The project involved collaboration with a technology manufacturer company, and the students gave the company a sustainable solution. They have taken this collaboration positively and seem to have a growing interest in partnering through the project course."
P 91: "The college conducted a workshop, which around 150 entrepreneurs and business leaders participated in. It was focused on developing resilient business practices with a sustainability strategy."
P 76: "A few of my students are engaged with the Tata Group on a project focusing on developing renewable energy for rural schools. The collaboration has led to a course redesign and the establishment of a co-curricular practicum".
P11: "We have programs to train our students for collaborations with local industries. However, I feel that with the integration into the global knowledge economy, the students have a shift in their sense of purpose. I feel that the concept of public good is taking a backseat, and revenue generation and profit making are given more importance".
P20: "The Placement Cell also helps us get many MOUs with the industry and conducts mandatory programs for students. Also, many of the students are hired as interns in companies to fulfil certain projects."

Theme 3: Lack of resources and delays in conducting the USR activities.
The challenges faced by the departments in conducting these activities were a shortage of funds and human resources, lack of support from administration (delays in approvals), poor communication, bureaucratic setup, and shortage of infrastructure. The participants also expressed concerns about low community engagement in social responsibility activities, the need for building local capacity, transparency issues, a narrower perception of social responsibility, a lack of consensus on implementing social responsibility initiatives, and cultural differences among students in a classroom also impacted productivity due to varying perspectives on fulfilling social responsibility. Apart from all these, many leaders raised concerns over environmental challenges like poverty and higher taxes as impediments to fulfilling social responsibility. A few excerpts of the interview are as follows:
P 42: "Cultural diversity and indifference also pose a challenge to implementing social responsibility since we have a lot of foreign students here."
P 73: "Lack of community participation hinders the proper implementation of social responsibility."
P 13: "The universities prioritize cost concerns and competitive advantage over societal health, security, and ecological development. I don't think they are willing to spend much on such activities".
P 98: " Most of the students are doing projects with government funding that undergoes annual audits, and this leads to potential interruptions in project continuity. Since universities are constrained by stringent public sector accounting regulations that are basically aimed at preventing fraud and protecting stakeholders, we face challenges in project implementation, mainly in procurement and resource utilization."
P 57: "Many times, I have helped my students get funding from my own funds, which had been allocated to me as an HOD for external uses, so that my students could go ahead with the project."
P 38: "Sometimes, the students need technical help for the project, and hiring professional or technical personnel is again a financial problem."
P 89: "Diverse contexts and students from various backgrounds in a classroom pose a challenge to carry out a project as the foreign students might not feel a sense of belongingness to the people.

Theme 4: Different ways to inculcate social responsibility amongst students

The responsibility towards society was inculcated by the faculty in students through numerous ways like classroom learning, social practices (assigning a social project in co-project mentoring, expert lectures, conferences and workshops in operation with NGO's or mentoring by experts. Involvement of students in business clubs, eco clubs , rotary club, seminars, worshops, discussing real case studies in the classroom, involvement as drishti and NSS mentors and motivating them by becoming their models. Students were involved into various societies like ENACTUS, discussion of SDG's in the classroom, conducting awareness through workshops etc. Students also engaged in practical learning like arranging a visit to the slums to know the problems of the desolate and come up with low cost effective, innovative solutions for the same and in this way inequalities in the society could be reduced by uprooting the poor and letting them enjoy equal access to technologies. Community engagement had been emphasized by a lot of leaders. Many faculty said that they had certain courses designed to inculcate the values of social responsibility and some colleges had an additional paper of Human Values and Ethics.

Some excerpts from the interviews are as follows:

P 35: " Practical learning is needed. My students have installed a low cost water pump in the nearby slum to solve the problem of shortage of water. The students are also associated with many social organizations".We have rain water harvesting in our college. Apart from this,there are posters in toilets for saving water and in the classrooms for switching off lights when not in use".

P 47: "Activities outside the college are conducted like the sikh community in our college does donations, langar sewa especially in times of covid like situations or any other natural calamities".

P92: "We do design projects on socially relevant issues (maybe from education, healthcare, water and sanitation, sustainability, smart cities domains and so on). Hence, our students are trained to not just value but actually empathise and resolve the problems of stakeholders in the social environment".

P 8: "Biological Sciences students generated diverse health campaign materials for partner communities, addressing shared health concerns. These materials had been distributed as digital files and the partners got them printed and disseminated them within their respective communities.

The faculty also pointed out how they would know whether a student actually undergoes a change after engaging in a USR activity.

P 66: "I don't evaluate them but one can feel the change through discussions".

P 28: "When they became very knowledgeable and through expertise, I can feel that they have it in them now".

The faculty also made sure that the students had inherited the USR values in them by discussions, conducting counselling, assigning them marks in their projects for USR activities conducted by the students, classroom interaction, All round assessment test, viva, portfolio management, feedback forms, All round assesment test, viva, portfolio management, feedback from staff, quiz test, conducting presentations ,Pre and post test of how their business ideas have changed drastically after undergoing USR activities etc. Participants expressed how students are able to comprehend the urgency of climate change at the local and global level and via joint communications, they will seek collaborative solutions. The faculty also promoted social responsibility not only in education but in research as well. They inspired the students to get real experiences and turn those community insights into research projects thereby returning the outcomes to benefit the community. This was done through projects, debates, and teamwork which sparked an interest in the real-world issues and cultivated the necessary skills in the students to address them. The faculty promoted a positive attitude toward volunteering and teamwork among students, familiarized them with diverse organizational environments through project participation and evaluated student's theoretical knowledge effectively.

P 09: "Partnering with day care centers, orphanages enables the students to understand team work".

Table: Approach of colleges towards fulfilment of SDG's

SDG	Initiatives taken by HEI's
Goal 1: No poverty	Woollen clothes distribution, programs like adopt five villages nearby colleges, medicines to needy people etc.
Goal 2: Zero Hunger	Nutrition application, Community kitchen initiatives.
Goal 3: Good health and Well being	Blood donation, Health camps, Sleep awareness program for patients.
Goal 4: Quality Education	Teaching in slums
Goal 5: Gender Equality	Gender sensitisation campaigns
Goal 6: Clean Water And Sanitation	Campaigns for saving water, Waste treatment plant, Rainwater harvesting
Goal 7: Affordable And Clean Energy	Biogas plant for lighting, fly ash brick construction, wind energy emulators, fuel cell setups.
Goal 8: Decent Work And Economic Growth	Incubation centres for funding and startup culture.
Goal 9: Industry, Innovation and Infrastructure	Pilot scale reactor for plastic waste, Various energy storage technologies.
Goal 10: Reduced Inequalities	HEI's give quotas and scholarships to students for particular sections of the society.
Goal 11: Sustainable Cities And Communities	Green Technology, Yule e-bikes
Goal 12: Responsible Consumption and Production	Segregating paper and plastic collection, special waste management, composting of garden waste.
Goal 13: Climate Action	Rooftop solar panels, on-site composting and disposal
Goal 15: Life On Land	Tree planting, park cleaning, waste recycling, bio resource recycling
Goal 17: Partnerships for the Goals	Partnership with Tata power for solar rooftops.

Source: Made by the authors

Conclusion

Education must prioritize the integration of the 17 UN Sustainability Goals, with University Social Responsibility (USR) as a cornerstone reflecting ethical engagement for holistic development. Overcoming barriers such as resistance to change and financial constraints is essential for implementing sustainable practices. Despite challenges, many universities champion social responsibility in critical areas. Institutions should align with international benchmarks, forge strategic partnerships, and integrate USR into strategic planning to fortify their societal impact. Fostering student awareness and promoting University Social Responsibility (USR) is imperative for cultivating graduates with enhanced capabilities and a commitment to addressing societal challenges. There is a need for comprehensive approach to global sustainability. Universities need to enhance visibility of their actions and engage various stake

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Limitation and Recommendation

The deliberate choice of qualitative study methods restricts the generalizability of the findings. Further, interviews included only the STEM leaders and not the rest of the faculty in a department. Our study suggests some specific recommendations as experienced by the STEM leaders.

Diversified funding achieved through collaboration with local and global stakeholders is crucial for aligning educational efforts with industry and societal needs. Higher learning institutions should allocate budgetary provisions to prioritize implementing social responsibilities as a core activity in higher education. Partnerships/collaboration between universities and government/civil society/corporates can yield additional funding and research opportunities for USR activities. The government can mandate legislation and enforce strategies to ensure that HEIs prioritize and implement social responsibility to the public. University leaders can drive Social Responsibility (SR) by incorporating it into organizational strategy, creating dedicated units and roles, and aligning rewards (compensation, awards for impactful teaching and research) and performance evaluation measures (volunteering, advisory services). This establishes an essential infrastructure for collaboration with external stakeholders and internal legitimacy for social responsibility.

The universities should engage in Service-learning. It integrates learning objectives with community service to offer a practical and progressive educational experience that addresses societal needs. E.g., courses, mentoring programs, student initiatives, and internships. Service-Learning and Civic Engagement aim for the common good, offering exceptional opportunities for civil society, students, and lecturers to apply academic knowledge to address social needs within a community context. Integrating various Service-Learning formats into the curriculum ensures institutional sustainability and fosters the acknowledgment of social responsibility in higher education. Universities should incorporate the SDGs (Sustainable Development Goals) into their teaching and learning by adding undergraduate courses which address them and make sure that this learning makes a difference in the world. They shouldn't have a motto to adopt it to improve their university rankings but through these reforms instill a sense of social responsibility not only in academic work but also in other functions that link universities with real-world problems. Sustainability rankings, accreditation standards emphasizing social impact, and funding instruments for sustainable development significantly shape organizational practices for social responsibility and impact assessment in universities. These mechanisms create benchmarks, standards, and financial incentives that drive institutions to prioritize and enhance their commitment to sustainable and socially responsible practices.

holders for greater effectiveness and to enhance organizational identity.

Declarations

Ethics approval and consent to participate

Both authors approve of the ethics and consent to participate. Institutional approval was taken prior to the primary data collection.

Consent for publication

Both authors have given their consent for publication. The research participants have also given their consent for publication, but their identities will remain anonymous.

Competing interests

Both authors have no competing interests.

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