

Gender inclusion in India's mining sector: A comparative analysis of female workforce representation in Coal India Limited and Tata Steel

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Abstract---Women's participation in mining has historically remained limited due to occupational segregation, institutional constraints, workplace conditions, and gender-related barriers. This study examines female workforce representation in Coal India Limited (CIL) and Tata Steel over ten financial years, from 2015–16 to 2024–25. Secondary data from the annual reports of both organisations were used, with female workforce representation measured as the percentage of women in the reported workforce. Descriptive statistics, paired-samples *t*-test, Shapiro–Wilk test, exact Wilcoxon signed-rank test, and linear regression were employed. Mean female representation was 7.58% in CIL and 7.14% in Tata Steel. The paired *t*-test showed no statistically significant difference at the 5% level, $t(9) = 2.053$, $p = .070$, whereas the exact Wilcoxon test indicated a significant difference ($p = .049$). Both organisations showed significant positive trends, with representation increasing by 0.248 percentage points annually in CIL and 0.415 percentage points in Tata Steel. The difference between the organisations also declined significantly over time, by 0.167 percentage points annually ($p = .014$). Overall, female representation increased in both organisations, although the comparative results should be interpreted cautiously given the ten annual observations.

Keywords---Gender inclusion, women in mining, female workforce representation, Coal India Limited, Tata Steel.

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1. Introduction

Mining has historically been characterised by substantial gender segregation, with women experiencing limited participation in many mining occupations. Cultural expectations, occupational structures, workplace conditions and institutional practices have contributed to the continued concentration of men in mining employment. Although changes in legislation and organisational practices have expanded opportunities for women, increased formal access to employment does not necessarily result in proportional representation within the workforce.

The Indian mining sector provides an important context for examining these developments. Coal India Limited (CIL) and Tata Steel represent two major organisations operating in India's mining and heavy-industrial environment, but they differ in organisational ownership and institutional structure. CIL operates as a public-sector enterprise, while Tata Steel represents a private-sector corporate organisation. These differences provide a useful basis for examining whether patterns of female workforce representation vary across organisational settings.

Female workforce representation is an important, although limited, indicator of gender inclusion. It captures the proportion of women present in the workforce but does not by itself explain recruitment, retention, promotion, occupational distribution or working conditions. Therefore, changes in the percentage of female employees should be interpreted as changes in workforce composition rather than as direct evidence of the causes of gender inclusion or exclusion.

Existing research has examined gender segregation, women's participation and institutional barriers in mining, but comparative longitudinal evidence involving major Indian mining organisations remains relatively limited. In particular, there is value in examining whether female workforce representation has changed systematically over an extended period and whether the difference between two major organisations has changed over time.

The present study therefore compares female workforce representation in CIL and Tata Steel for ten consecutive financial years, from 2015–16 to 2024–25. Unlike a short-term comparison, the ten-year period permits examination of both the average difference between the organisations and the direction of change over time. The study specifically addresses whether the observed annual representation levels differ between CIL and Tata Steel and whether female representation has demonstrated a systematic temporal trend.

2. Theoretical Framework

2.1 Gender Segregation Perspective

Gender segregation provides a useful framework for understanding women's historically limited participation in mining. Occupational segregation may occur when men and women become concentrated in different occupations or job categories, while vertical segregation may arise when women have limited representation at higher organisational levels. The traditionally male-dominated character of mining makes gender segregation particularly relevant to the sector.

2.2 Institutional Perspective

Institutional theory suggests that organisational practices are influenced by regulatory requirements, established norms and expectations within the wider institutional environment. Differences in ownership structure, organisational procedures and external expectations may therefore be associated with differences in workforce composition. In the present study, this perspective provides a framework for comparing female representation across a public-sector and a private-sector organisation without assuming that organisational structure itself establishes causality.

2.3 Labour Market Segmentation Perspective

Labour market segmentation distinguishes between different forms of employment based on characteristics such as employment security, working conditions and organisational arrangements. Since the present study focuses on reported workforce representation, this perspective is useful for recognising that aggregate female representation may conceal differences across occupational and employment categories.

3. Literature Review

Previous research has documented the persistent gendered character of mining employment. Lahiri-Dutt (2012) examined women's position in mining and highlighted the importance of gender relations, occupational structures and social expectations in shaping women's participation in extractive industries. Research on mining workplaces has similarly emphasised the role of workplace culture and structural barriers in limiting women's participation.

Studies of gender and mining also indicate that formal regulatory change does not automatically eliminate occupational gender disparities. Changes in legal provisions may increase women's formal opportunities, while organisational practices, workplace conditions and social norms continue to influence actual participation.

The literature therefore establishes three relevant points for the present study. First, mining has historically been male dominated. Second, institutional and organisational conditions can influence women's participation. Third, aggregate workforce representation provides an observable indicator through which changes in women's presence can be examined over time.

However, the existing literature does not adequately address the specific ten-year comparative pattern of female workforce representation between CIL and Tata Steel. This provides the basis for the present longitudinal comparison.

4. Research Gap

The existing literature provides substantial discussion of gender segregation and women's participation in mining, but comparatively limited empirical evidence is available on the longitudinal workforce representation of women in major Indian mining organisations.

Three gaps are particularly relevant.

First, much of the existing discussion focuses on the general experience of women in mining rather than comparing the workforce composition of major organisations.

Second, studies often use cross-sectional or limited-period evidence, whereas a longer annual series can reveal whether observed differences persist, narrow or change over time.

Third, differences between organisations are sometimes attributed directly to organisational policies or institutional characteristics without statistically examining the observed workforce data.

The present study addresses these gaps by analysing ten years of reported female workforce representation in CIL and Tata Steel and by combining descriptive, paired-comparison and trend-based statistical analysis.

5. Objectives of the Study

The study has the following objectives:

1. To examine the level and pattern of female workforce representation in CIL and Tata Steel from 2015–16 to 2024–25.
2. To compare the female workforce representation of CIL and Tata Steel across the study period.
3. To examine whether female workforce representation has changed systematically over time in each organisation.

4. To examine whether the difference in female workforce representation between the two organisations has changed over the study period.

6. Hypotheses

H₀: There is no statistically significant difference in female workforce representation between CIL and Tata Steel across the study period.

H₁: There is a statistically significant difference in female workforce representation between CIL and Tata Steel across the study period.

For the trend analysis, the study additionally examines whether the coefficient of the year variable is statistically different from zero in the respective regression models.

7. Methodology

7.1 Research Design

The study adopts a longitudinal comparative research design based on secondary organisational data. The analysis covers ten financial years, from 2015–16 to 2024–25, and compares Coal India Limited and Tata Steel.

7.2 Data Source

The study uses gender-disaggregated workforce information reported in the annual reports of CIL and Tata Steel. The annual reports constitute the primary source of the data used in the analysis.

The final dataset contains ten annual observations for each organisation. The female workforce representation percentages were personally verified against the respective annual reports before statistical analysis.

7.3 Variable

The principal variable is:

Female Workforce Representation (%)

This represents the reported percentage of women in the workforce for each financial year.

The study uses percentage representation as the principal comparative measure rather than absolute numbers because CIL and Tata Steel have substantially different workforce sizes. Absolute female employee numbers are therefore presented, where relevant, as supplementary information rather than as the principal basis of comparison.

7.4 Statistical Techniques

The following techniques were applied:

Descriptive statistics

Mean, standard deviation, median, minimum and maximum values were calculated to describe the distribution of female workforce representation.

Paired-samples t-test

Because CIL and Tata Steel observations are matched by the same financial years, a paired-samples *t*-test was used to examine whether the mean within-year difference in female workforce representation was statistically different from zero.

Shapiro–Wilk test

The normality of the paired differences was assessed using the Shapiro–Wilk test.

Wilcoxon signed-rank test

Because the number of annual observations is small, the Wilcoxon signed-rank test was additionally employed as a non-parametric robustness check. The exact significance value was considered because of the small sample of matched observations.

Linear trend regression

Separate linear regression models were estimated for CIL and Tata Steel using the sequential year index as the independent variable. A further regression examined whether the difference between the two organisations changed systematically over time.

The statistical analysis was performed using SPSS.

7.5 Interpretation of Statistical Inference

The unit of analysis in this study is the organisation-year observation, not the individual employee. The ten observations therefore represent ten consecutive annual measurements for each organisation. Statistical results are interpreted as evidence concerning the observed ten-year series rather than as employee-level population estimates.

The study is also observational and does not attempt to establish causal relationships between organisational characteristics and female workforce representation.

8. Results and Analysis

8.1 Descriptive Statistics

Table 1 presents the descriptive statistics for female workforce representation in CIL and Tata Steel over the ten-year study period.

Table 1. Descriptive Statistics of Female Workforce Representation

Statistic	CIL (%)	Tata Steel (%)
N	10	10
Mean	7.583	7.141
Median	7.305	6.900
Standard deviation	0.812	1.350
Minimum	6.76	5.50
Maximum	9.08	10.00

CIL recorded a mean female workforce representation of 7.583%, compared with 7.141% for Tata Steel. The median values were 7.305% and 6.900%, respectively. CIL also recorded lower annual variability, with a standard deviation of 0.812 percentage points compared with 1.350 percentage points for Tata Steel.

The range of Tata Steel's observations was larger, extending from 5.50% in 2015–16 to 10.00% in 2024–25. CIL's corresponding range was 6.76% to 9.08%. Thus, the descriptive evidence indicates that CIL had a slightly higher average representation over the full period, while Tata Steel experienced greater year-to-year variation.

8.2 Year-wise Female Workforce Representation

Table 2. Female Workforce Representation, 2015–16 to 2024–25

Financial Year	CIL (%)	Tata Steel (%)	Difference (CIL – Tata)
2015–16	7.07	5.50	1.57

Financial Year	CIL (%)	Tata Steel (%)	Difference (CIL – Tata)
2016–17	6.78	5.80	0.98
2017–18	6.76	6.11	0.65
2018–19	6.93	6.50	0.43
2019–20	7.03	6.90	0.13
2020–21	7.54	7.40	0.14
2021–22	7.89	6.90	0.99
2022–23	8.27	8.30	–0.03
2023–24	8.48	8.00	0.48
2024–25	9.08	10.00	–0.92

Source: Annual Reports of Coal India Limited and Tata Steel Limited; calculations based on verified annual-report data.

The year-wise series shows that CIL's representation remained between 6.76% and 9.08% throughout the study period. After relatively lower values during 2016–17 and 2017–18, CIL's representation increased to 9.08% by 2024–25.

Tata Steel began the period with a lower representation of 5.50%. Its representation increased gradually until 2020–21, followed by a decline to 6.90% in 2021–22. It subsequently reached 8.30% in 2022–23, declined to 8.00% in 2023–24, and increased to 10.00% in 2024–25.

The two series therefore display different year-to-year movements, but both end the study period at higher levels than their respective starting values.

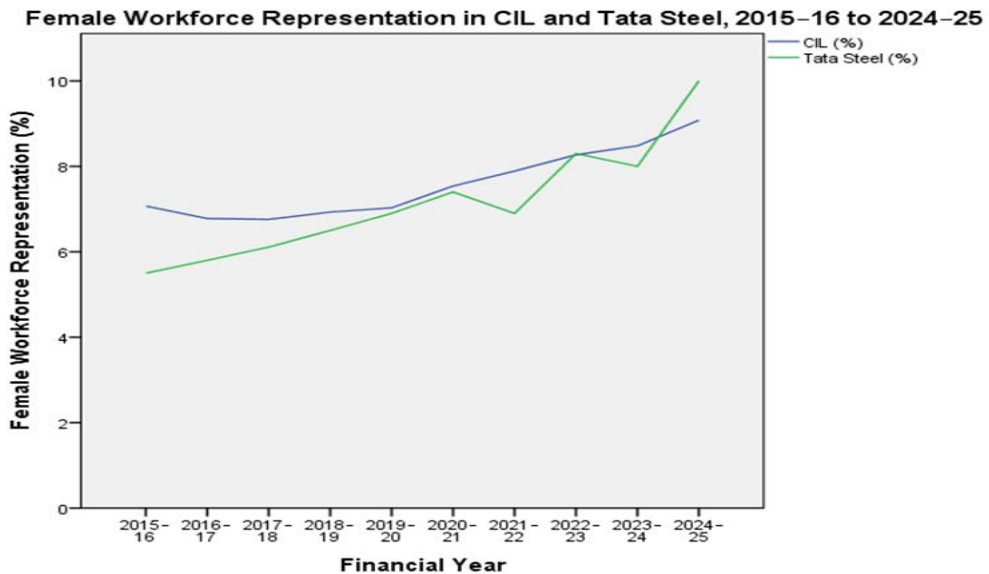


Figure 1. Female Workforce Representation in CIL and Tata Steel, 2015–16 to 2024–25

The line graph illustrates the changing relationship between the two series. CIL remained above Tata Steel during most of the earlier years, while the two organisations converged around 2022–23. Tata Steel subsequently recorded a higher value in 2024–25.

8.3 Paired Comparison

Because each CIL observation is matched with the corresponding Tata Steel observation for the same financial year, a paired-samples analysis was conducted.

The mean paired difference was:

CIL – Tata Steel = 0.442 percentage points

The 95% confidence interval for the mean difference was **–0.045 to 0.929 percentage points**.

The paired-samples *t*-test produced:

$t(9) = 2.053, p = .070$

Since the *p*-value exceeds the 5% significance level, the null hypothesis is not rejected on the basis of the paired *t*-test. Thus, the data do not provide sufficient evidence of a statistically significant mean difference between the two organisations at the conventional 5% level.

The Shapiro–Wilk test applied to the paired differences produced:

$W = .969, p = .881$

There was therefore no statistically significant evidence of non-normality in the paired differences.

However, given the small number of annual observations, a non-parametric robustness check was also performed.

The exact Wilcoxon signed-rank test produced:

$Z = -1.988$, exact two-tailed $p = .049$

The Wilcoxon result therefore indicates a statistically significant difference at the 5% level. The two tests do not produce identical conclusions: the paired *t*-test does not reach the 5% threshold, whereas the exact Wilcoxon test does.

This difference is important for interpretation. Rather than presenting either test selectively, the results suggest that the statistical evidence concerning the difference between the organisations is sensitive to the method used. The small number of annual observations further supports a cautious interpretation.

8.4 Trend Analysis

Separate linear regression models were estimated for CIL and Tata Steel, using a sequential year index from 1 to 10 as the independent variable.

Table 3. Linear Trend Regression

Statistic	CIL	Tata Steel
R	.925	.932
R ²	.856	.868
Adjusted R ²	.838	.852
Slope (B)	.248	.415
t	6.893	7.256
F(1,8)	47.519	52.652

The regression results indicate a statistically significant positive linear trend for both organisations.

For CIL, the estimated coefficient of 0.248 indicates an average increase of approximately 0.248 percentage points in female workforce representation per year. The model explains 85.6% of the variation in the observed annual CIL series ($R^2 = .856, p < .001$).

For Tata Steel, the estimated coefficient is 0.415 percentage points per year. The model explains 86.8% of the variation in the observed annual series ($R^2 = .868, p < .001$).

These results indicate that female workforce representation increased systematically over the study period in both organisations. The estimated slope is larger for Tata Steel, although this should be interpreted as a difference in the observed rate of change rather than evidence that a particular organisational policy caused the difference.

8.5 Change in the CIL–Tata Steel Gap

To examine whether the difference between the two organisations changed over time, the annual difference was calculated as:

Difference = CIL – Tata Steel

A linear regression of this difference on the year index produced the following results:

Table 4. Regression of the CIL–Tata Steel Difference on Time

Statistic	Result
R	.744
R ²	.554
Adjusted R ²	.498
Slope (B)	−0.167
T	−3.152
F(1,8)	9.934
p-value	.014
95% CI for slope	−0.290 to −0.045

The coefficient of −0.167 indicates that the CIL-minus-Tata Steel difference declined by approximately 0.167 percentage points per year over the study period. The trend was statistically significant ($p = .014$). The observed values support this pattern. CIL's representation exceeded Tata Steel's by 1.57 percentage points in 2015–16, whereas Tata Steel exceeded CIL by 0.92 percentage points in 2024–25.

Thus, the relative difference between the two organisations narrowed over the study period and eventually changed direction. This finding complements the separate trend regressions: both organisations increased their female representation, but Tata Steel's estimated rate of increase was higher.

9. Discussion

The results provide evidence of a broad increase in female workforce representation in both CIL and Tata Steel during 2015–16 to 2024–25. The two organisations, however, did not follow identical annual patterns. CIL recorded the higher ten-year mean, at 7.58%, compared with 7.14% for Tata Steel. Nevertheless, the difference in mean representation was not statistically significant according to the paired *t*-test at the 5% level. The exact Wilcoxon test produced a marginally significant result. The contrasting results indicate that conclusions about the difference between the organisations should not be based on a single statistical test.

The trend analysis provides a clearer and more consistent finding. Both organisations experienced statistically significant positive trends. CIL's estimated increase was 0.248 percentage points per year, while Tata Steel's estimated increase was 0.415 percentage points per year. The larger coefficient for Tata Steel is consistent with its movement from 5.50% in 2015–16 to 10.00% in 2024–25. The regression of the difference between the organisations further indicates that the initial advantage held by CIL narrowed over time. By 2022–23, the two organisations were almost equal, and Tata Steel subsequently exceeded CIL in 2024–25.

These findings should nevertheless be distinguished from explanations concerning the causes of the observed changes. Workforce representation data alone cannot establish whether changes resulted from recruitment policies, regulatory developments, organisational diversity programmes, changes in occupational deployment, workforce restructuring or other factors. The present analysis identifies patterns of workforce representation, rather than estimating the effects of specific organisational interventions.

The findings therefore support a more cautious interpretation of gender inclusion in mining. Both organisations show measurable improvement in female workforce representation over the ten-year period, while the relative position of the two organisations changed over time. The results also demonstrate the value of longitudinal organisational data because a comparison based only on the

beginning or ending year could produce a different interpretation from one based on the complete annual series.

10. Limitations

The study has several limitations.

First, the analysis is based on only ten annual observations per organisation. Consequently, the statistical results should be interpreted cautiously and should not be treated as equivalent to large-sample employee-level inference.

Second, the study measures gender inclusion primarily through female workforce representation. This indicator does not capture women's distribution across occupations, managerial levels, mining locations, wages, promotion, retention or working conditions.

Third, the analysis is based on reported organisational data. Differences in reporting practices, workforce definitions and reporting boundaries may affect comparability across years and organisations. The study therefore relies on the figures reported in the respective annual reports and does not attempt to reconstruct unpublished workforce information.

Fourth, contract and outsourced workers are not used as the principal basis of comparison because consistently comparable gender-disaggregated information is not available across the full study period.

Finally, the observational design does not permit causal conclusions. The study identifies statistical associations and temporal patterns but cannot determine whether particular organisational policies or institutional characteristics caused changes in female workforce representation.

11. Conclusion

This study examined female workforce representation in Coal India Limited and Tata Steel over ten financial years from 2015–16 to 2024–25. The analysis provides evidence of increasing female representation in both organisations during the study period. CIL recorded a ten-year mean representation of 7.58%, compared with 7.14% for Tata Steel. The paired-samples *t*-test did not identify a statistically significant mean difference at the 5% level, although the exact Wilcoxon signed-rank test produced a statistically significant result. The differing results indicate that the comparison between the organisations should be interpreted cautiously rather than reduced to a simple significant/non-significant conclusion.

The most consistent finding concerns the direction of change over time. Both CIL and Tata Steel exhibited statistically significant positive linear trends. CIL's estimated annual increase was 0.248 percentage points, while Tata Steel's was 0.415 percentage points. The regression of the inter-organisational difference also showed a significant downward trend, indicating that the initial difference between the organisations narrowed over the study period and eventually changed direction.

The study therefore demonstrates that female workforce representation in both organisations moved upward during the decade, while their relative positions changed over time. These findings provide empirical evidence of changing gender composition within two major Indian mining organisations. However, workforce representation alone cannot establish the reasons behind these changes. Future research should therefore extend the analysis to occupational categories, recruitment, retention, managerial representation, wages, working conditions and mine-level data.

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