

INDUSTRIAL CLUSTERS, TECHNOLOGY ADOPTION, AND EMPLOYMENT OUTCOMES: EVIDENCE FROM THE TMT BAR AND IRON MANUFACTURING SECTOR IN INDIA

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Abstract:

This study examines industrial growth and employment dynamics in the Thermo-Mechanically Treated (TMT) bar and iron manufacturing sector of Muzaffarnagar district, Uttar Pradesh, through the lens of industrial cluster theory, skill-biased technical change, and MSME-led regional development. Using a mixed-methods approach, primary data were collected from 60 manufacturing units and workers through structured surveys, key informant interviews, and focus group discussions, supplemented by secondary policy and industry sources. Quantitative analysis reveals a strong positive relationship between production scale and direct employment, while higher levels of technology adoption reduce labour intensity without diminishing total employment, indicating a shift in labour demand toward semi-skilled workers. Qualitative findings highlight that cluster-level constraints—particularly weak institutional coordination, inadequate shared infrastructure, skill shortages, and power supply instability—limit the translation of output growth into improved employment quality. The study extends industrial cluster theory by demonstrating that employment outcomes depend not only on geographic concentration but also on governance capacity and collective facilities. It further contributes to skill-biased technical change literature by providing district-level evidence from an MSME-dominated manufacturing cluster in a developing economy. By integrating employment quantity and employment quality into MSME performance assessment, the study offers a conceptual framework with broader applicability to regional industrial clusters in emerging economies.

Keywords: Industrial clusters; TMT bars; iron and steel industry; MSMEs; employment quality; skill-biased technical change; regional development.

1. INTRODUCTION

Manufacturing-led development remains a central pillar of India's economic growth strategy, particularly for employment creation and regional industrialization. Among manufacturing subsectors, the iron and steel industry holds a strategic position due to its strong forward and backward linkages with infrastructure, housing, transport, and capital goods industries. Thermo-Mechanically Treated (TMT) bars, a downstream steel product, are a critical input for reinforced concrete construction and thus play a vital role in India's infrastructure and real estate expansion.

Muzaffarnagar district in Western Uttar Pradesh has emerged as a prominent regional hub for TMT bar manufacturing, iron rolling mills, scrap processing, and allied fabrication units. The sector is dominated by micro, small, and medium enterprises (MSMEs) operating within a cluster-based industrial structure. These enterprises provide substantial direct and indirect employment to semi-skilled and unskilled workers drawn largely from rural and peri-urban areas, thereby contributing to livelihood diversification and poverty reduction.

Despite its economic importance, the sector faces several structural challenges. Persistent power supply disruptions, rising raw material costs, limited access to formal finance, skill shortages, and regulatory compliance burdens constrain productivity and growth. Moreover, while employment generation is

significant, the quality of employment in terms of wages, job security, occupational safety, and skill development remains uneven. These issues underline the need for a systematic empirical assessment of industrial growth and employment dynamics at the district level.

This study seeks to address this gap by analysing production patterns, employment generation, workforce characteristics, and growth constraints in the TMT bar and iron sector of Muzaffarnagar. The study further proposes policy-relevant interventions aimed at enhancing productivity, employment quality, and long-term sustainability of the cluster.

2. REVIEW OF LITERATURE

2.1 Iron and Steel Industry in India

India's iron and steel industry has recorded substantial growth over the past decade, driven by infrastructure development, urbanisation, and industrial expansion. National-level studies highlight the role of downstream steel products, particularly TMT bars, in meeting construction demand. However, much of the production and employment generation occurs in small re-rolling and fabrication units that operate outside the large integrated steel plants.

2.2 MSME Clusters and Regional Development

The literature on industrial clusters emphasises their role in enhancing competitiveness, fostering innovation, and generating employment. MSME-dominated clusters, especially in metal processing, benefit from shared labour markets, supplier networks, and market proximity. At the same time, they are often constrained by small scale of operation, outdated technology, and limited institutional capacity.

2.3 Employment and Productivity in Small Manufacturing Units

Empirical studies on Indian manufacturing indicate that labour-intensive MSME sectors generate large volumes of employment but often at modest wage levels. Productivity improvements through mechanisation and technology adoption can raise output, but may also reduce labour intensity unless accompanied by skill upgrading. Contractual and informal employment arrangements are common in small metal units, reflecting cost pressures and demand volatility.

2.4 Skills, Technology, and Common Facilities

Several studies highlight skill shortages and inadequate training as key constraints in metal-processing industries. Policy-oriented research advocates the establishment of Common Facility Centres (CFCs) to provide shared access to testing laboratories, quality certification, maintenance services, and training infrastructure. Such interventions are viewed as cost-effective mechanisms for enhancing productivity and product quality in MSME clusters.

2.5 Research Gap

While existing literature provides valuable insights at the national and state levels, there is limited district-level empirical research that integrates firm-level production data, employment quality indicators, and cluster governance capacity. This study contributes to the literature by offering a holistic case study of the TMT bar and iron sector in Muzaffarnagar.

2.6 Theoretical Framework and Conceptual Model

2.6.1 Industrial Cluster Theory

Industrial Cluster Theory argues that geographically concentrated firms operating within the same value chain benefit from shared labour markets, supplier networks, knowledge spillovers, and reduced transaction costs. Classical and contemporary cluster literature suggests that MSME-dominated clusters can achieve collective efficiency even when individual firms remain small and resource-constrained.

In the context of iron and TMT manufacturing, clustering facilitates access to scrap suppliers, transporters, semi-skilled labour, and construction markets. However, the theory also highlights that clusters may suffer from collective action failures—particularly in infrastructure provision, skill development, and technology upgrading—if institutional coordination is weak.

The present study extends cluster theory by demonstrating that while Muzaffarnagar’s TMT–iron cluster generates substantial employment, the absence of shared facilities (testing labs, training centres, power solutions) constrains productivity and employment quality. Thus, cluster benefits are partially realised but institutionally incomplete, offering empirical support for the argument that governance capacity determines cluster outcomes.

2.6.2 Labour Demand and Skill-Biased Technical Change

The theory of Skill-Biased Technical Change (SBTC) posits that technological adoption increases demand for skilled labour while reducing reliance on unskilled labour, thereby altering employment composition rather than eliminating jobs entirely. In manufacturing, automation often reduces labour intensity per unit of output but can increase total employment through output expansion.

The regression results in this study align with SBTC predictions: production scale is positively associated with employment, while higher technology intensity reduces labour per unit of output. Importantly, the findings indicate that technology adoption does not reduce total employment in the cluster; instead, it shifts labour demand toward semi-skilled machine operators and maintenance workers.

This study therefore contributes to SBTC literature by providing district-level empirical evidence from a developing-economy MSME cluster, showing that selective mechanisation combined with skill upgrading can balance productivity growth with employment generation.

2.6.3 MSME-Led Regional Development

MSME-led development theory emphasises the role of small firms in generating employment, absorbing surplus labour, and promoting regional industrial diversification. Unlike capital-intensive large firms, MSMEs are labour-absorbing and regionally embedded, making them crucial for inclusive growth.

The Muzaffarnagar TMT–iron sector exemplifies this model. The cluster absorbs semi-skilled rural labour, supports backward linkages with scrap suppliers, and strengthens forward linkages with infrastructure and housing projects. However, employment quality remains constrained due to informality, limited training, and safety deficits.

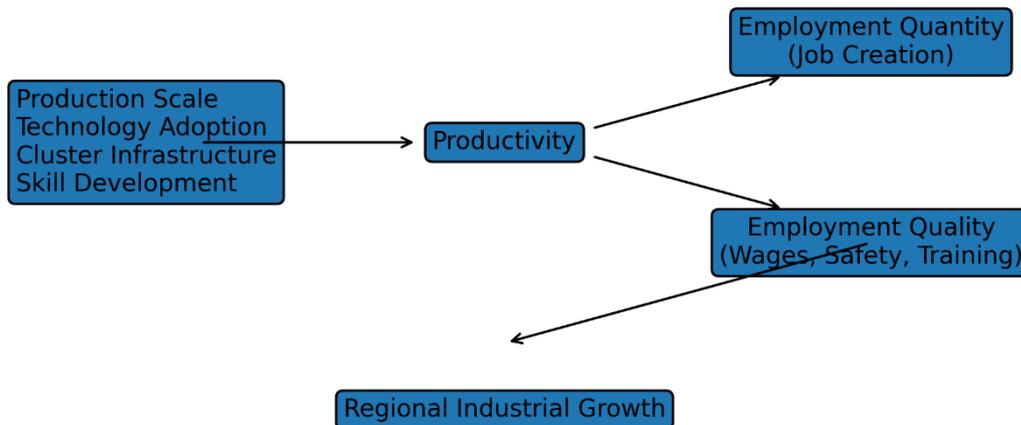
This study advances MSME development theory by highlighting that employment quantity alone is insufficient; employment quality and sustainability must be incorporated into MSME performance assessments. The findings suggest that policy frameworks should evaluate MSMEs not only by output and employment numbers but also by training intensity, safety compliance, and wage stability.

2.6.4 Conceptual Framework

The conceptual framework can be described as:

Production Scale + Technology Adoption + Cluster Infrastructure + Skill Development
 → **Productivity** → **Employment Quantity** → **Employment Quality** → **Regional Industrial Growth**

Figure 1. - Conceptual Framework of Industrial Growth and Employment in the TMT–Iron Cluster



This framework integrates cluster theory, SBTC, and MSME development into a single analytical model.

3. OBJECTIVES OF THE STUDY

The specific objectives of the study are:

1. To assess the scale and growth of production in the TMT bar and iron manufacturing sector of Muzaffarnagar.
2. To quantify direct and indirect employment generated by the sector and analyse workforce characteristics.
3. To identify key constraints affecting industrial growth, productivity, and employment quality.
4. To propose policy and cluster-level interventions to support sustainable industrial development.

4. RESEARCH METHODOLOGY

4.1 Research Design

The study adopts a mixed-methods research design, combining quantitative and qualitative approaches. Structured questionnaires were used to collect firm-level and worker-level data, while key informant interviews and focus group discussions provided contextual and perceptual insights.

4.2 Sampling and Data Collection

A sample of 60 manufacturing units was selected using records from the District Industries Centre, industrial estate listings, and local business directories. Data were collected on firm age, production capacity, sales turnover, employment levels, technology adoption, training practices, and operational challenges.

4.3 Analytical Techniques

Descriptive statistics were used to summarise production and employment patterns. Pearson correlation analysis and ordinary least squares (OLS) regression were employed to examine the relationship between production scale, technology adoption, firm age, and employment generation. Qualitative data were analysed thematically.

5. RESULTS AND ANALYSIS

5.1 Industrial Structure and Production Trends

The Muzaffarnagar iron and TMT sector comprises TMT bar manufacturing units, iron rolling mills, scrap processing units, and allied fabrication firms. A majority of surveyed units reported positive production growth over the past five years, driven primarily by local construction demand and infrastructure projects.

5.2 Employment Generation and Workforce Profile

Average direct employment per firm was approximately 56 workers, with substantial indirect employment through transport, scrap supply, and ancillary services. The workforce is predominantly semi-skilled, with a significant share of workers holding ITI or diploma qualifications. Employment arrangements are largely contractual or daily-wage in nature.

5.3 Production–Employment Relationship

Regression analysis indicates a strong positive relationship between production volume and direct employment. Technology adoption exhibits a negative association with labour intensity, suggesting that mechanisation reduces the number of workers required per unit of output. Firm age shows a marginal negative effect, possibly reflecting efficiency gains in older units.

5.4 Constraints and Operational Challenges

The most frequently reported constraints include unreliable power supply, rising raw material costs, shortages of trained labour, and regulatory compliance requirements. Safety practices are partially implemented, with limited formal training in occupational health and safety.

Table 1- Descriptive Statistics of Key Variables in the TMT and Iron Manufacturing Sector (n = 60)

Variable	Mean	Minimum	Maximum	Standard Deviation
Firm Age (years)	14.8	2	25	7.3
Technology Index (1–5)	3.27	1	5	1.21
Monthly Production (tonnes)	688.43	50	1,950	412.6
Monthly Sales (₹ lakh)	53.12	2.29	115.24	29.8

Variable	Mean	Minimum	Maximum	Standard Deviation
Direct Employment (persons)	55.93	5	161	34.7
Indirect Employment (persons)	54.21	13	104	22.5
Workers Receiving Training (%)	36.4	7.8	57.5	14.6
Challenge Severity Score (1–5)	2.47	1.0	4.4	0.91

Source: Primary survey of TMT and iron manufacturing units in Muzaffarnagar district, 2024–25.

Table 1 presents descriptive statistics of the surveyed firms. The results indicate considerable variation in production scale and employment across units, reflecting the heterogeneous structure of the MSME-dominated TMT and iron manufacturing cluster.

Table 2
Pearson Correlation Matrix of Key Variables (n = 60)

Variable	(1) Monthly Production	(2) Technology Index	(3) Firm Age	(4) Direct Employment	(5) Training Intensity
(1) Monthly Production (tonnes)	1.000				
(2) Technology Index (1–5)	0.42***	1.000			
(3) Firm Age (years)	0.28**	0.31**	1.000		
(4) Direct Employment (persons)	0.87***	−0.46***	−0.19*	1.000	
(5) Training Intensity (%)	0.34**	0.49***	0.22*	0.41***	1.000

Notes:

- ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.
- Pearson correlation coefficients reported.
- Training Intensity measured as the percentage of workers receiving formal training annually.

Source: Authors' calculations based on primary survey data from TMT and iron manufacturing units in Muzaffarnagar district, 2024–25.

Table 2 shows a strong and statistically significant positive correlation between monthly production and direct employment, indicating high employment elasticity of output in the TMT and iron manufacturing cluster. Technology adoption is positively associated with production scale but negatively correlated with direct employment, supporting the skill-biased technical change hypothesis. Training intensity exhibits a positive association with both technology adoption and employment, underscoring the complementary role of skills in enhancing productivity through technological change.

6. DISCUSSION

The findings highlight the sector's dual role as an engine of employment generation and a contributor to regional industrial growth. While output expansion increases employment, unbalanced mechanisation without skill upgrading may limit job creation. Cluster-based interventions can help reconcile productivity improvements with employment objectives.

The findings of this study reinforce the theoretical proposition that industrial clusters generate employment primarily through scale expansion rather than labour intensity. The strong association between production volume and employment supports classical labour demand theory, while the negative relationship between technology intensity and labour per unit output aligns with skill-biased technical change.

Unlike large capital-intensive steel plants, MSME-based TMT and iron units retain a high employment elasticity due to their reliance on semi-skilled labour and flexible production processes. However, the study demonstrates that without complementary investments in skill development and shared infrastructure, productivity gains from technology adoption may not translate into improved employment quality.

From a cluster-theory perspective, the Muzaffarnagar case illustrates a “low-coordination equilibrium”, where firms benefit from geographic concentration but fail to achieve collective efficiency due to weak

institutional mechanisms. This finding contributes to the cluster literature by empirically showing how governance capacity mediates employment and productivity outcomes in MSME clusters.

7. POLICY IMPLICATIONS AND RECOMMENDATIONS

1. **Infrastructure Development:** Ensure a reliable power supply and improve internal industrial road connectivity.
2. **Skill Development:** Establish sector-specific training centres in collaboration with ITIs and industry associations.
3. **Technology Upgradation:** Facilitate access to subsidised credit and equipment leasing for MSMEs.
4. **Cluster-Based Facilities:** Develop common testing labs, maintenance hubs, and pollution control infrastructure.
5. **Labour Welfare:** Strengthen the enforcement of safety standards and provision of basic workplace amenities.

8. CONCLUSION

The TMT bar and iron manufacturing sector in Muzaffarnagar represents a strategically important MSME-led industrial cluster that supports regional employment and infrastructure development. Despite strong demand-driven growth, structural constraints related to infrastructure, skills, and compliance limit productivity and employment quality. Targeted policy support, improved infrastructure, and coordinated skill development initiatives can enable the sector to evolve into a sustainable and competitive manufacturing hub in Western Uttar Pradesh.

This study makes four key theoretical contributions:

1. It extends industrial cluster theory by demonstrating that employment outcomes depend not only on geographic concentration but also on institutional coordination and shared infrastructure.
2. It provides district-level empirical support for skill-biased technical change theory in an MSME-dominated manufacturing cluster in a developing economy.
3. It advances MSME-led development theory by incorporating employment quality—wages, safety, and training—as core performance dimensions.
4. It proposes an integrated conceptual framework linking production scale, technology adoption, skills, and employment outcomes, offering a transferable model for analysing similar industrial clusters in emerging economies.

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