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A production function approach with Indian JUGAAD perspective for Eastern World Countries

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Abstract. This research introduces a novel production function integrating the Indian Jugaad philosophy, emphasizing cost-effectiveness and adaptability in resource- constrained environments. Traditional production functions, such as Cobb-Douglas and CES, assume capital abundance and technological uniformity, making them less applicable in developing economies where capital constraints and technological iner- tia prevail. This study develops a nested production function incorporating capital intensity, labor intensity, and capital-labor interaction as a composite input. The theoretical foundation is reinforced by linking Jugaad to Schumpeterian innovation, institutional economics, and adaptive efficiency. A dynamic transition equation is introduced, demonstrating how firms either persist with Jugaad-based strategies or transition to capital-intensive production over time. Industry-wide equilibrium properties and spillover effects are analyzed and empirically estimated using firm- level data. Empirical validation using India's Annual Survey of Industries (ASI) across five industrial sectors demonstrates superior performance over Cobb-Douglas and CES models. Robustness checks, including cross-validation, AIC/BIC criteria, Hansen J-tests, Stock-Yogo weak-instrument tests, overidentification tests, and sen- sitivity analysis, confirm the model's predictive power. The findings provide action- able insights for policymakers aiming to optimize industrial efficiency in emerging economies.
Keywords. Jugaad innovation; Production function; Resource-constrained economies; Capital–labor interaction; Industrial efficiency.
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1. Introduction

Economic development in industrializing nations requires a production function that accounts for structural constraints, market imperfections, and technological heterogene- ity. Traditional production models assume well-functioning markets with seamless factor substitution and uniform technological progress, assumptions that rarely hold in capital-constrained economies. Jugaad, an Indian term for frugal innovation, represents a flexible and improvisational problem-solving approach widely used in industries with limited cap- ital. This study argues that embedding

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Jugaad within a structured production function enhances our understanding of industrial productivity in such settings.

2. Jugaad and Formal R&D: Complementary or Substitutes?

Jugaad is an endogenous firm-level strategy where firms innovate under capital constraints by adopting informal, adaptive techniques to enhance efficiency. Unlike Schumpeterian innovation, which emphasizes structured R&D investment, Jugaad is characterized by flexible capital-labor substitution, improvisational process innovation, and resource opti- mization under financial limitations.

An important question is whether Jugaad acts as a stepping stone to formal R&D- based innovation or remains a distinct long-run strategy. In capital-constrained indus- tries, Jugaad enables firms to optimize production without extensive capital investments. However, as firms grow and accumulate financial resources, they may transition toward structured R&D while still maintaining elements of Jugaad for process innovation. This hybrid model, where firms employ both Jugaad and formal R&D, is an area requiring further empirical exploration.

3. Firm Optimization Model and Dynamic Transition

Firms solve the following constrained optimization problem:

$$\max_{K,L} \Pi = PY - wL - rK + \phi \cdot f(J), \tag{1}$$

where P represents output price, w is the wage rate, r is the cost of capital, and $\phi f(J)$ captures efficiency gains from Jugaad. Here, J is a Jugaad intensity function, defined as:

$$J = \psi(K/L)^{\eta} + \lambda I_t, \tag{2}$$

where I_t represents firm-level improvisational efficiency, and ψ, λ are parameters capturing adaptive efficiency effects.

To capture long-run firm behavior, a transition equation is introduced:

$$\frac{dJ}{dt} = \zeta - \mu J + \theta \log(1 + E_t), \tag{3}$$

where ζ represents external constraints (e.g., capital scarcity) driving Jugaad adoption, μ represents the rate at which firms transition to conventional production, and E_t denotes experience accumulation, capturing learning-by-doing effects. In some industries, partic- ularly informal and small-scale sectors, Jugaad may remain optimal even as constraints ease, making it a long-run equilibrium strategy for certain firms.

4. The Nested Production Function and Equilibrium Properties

The proposed production function takes the form:

$$Y = A\ \alpha K\rho + \beta J\sigma + \gamma L\delta^{\ \theta}, \tag{4}$$

where A is total factor productivity (TFP), and J explicitly represents Jugaad-driven efficiency, capturing both capital-labor interactions and improvisational strategies. The elasticity parameters (ρ, σ, δ) are derived through first-order conditions and equilibrium constraints.
Industry-wide spillover effects are introduced via:

$$St = \xi \sum_i Ji, \tag{5}$$

where St denotes sectoral technological spillovers, and Ji represents Jugaad intensity across firms. Empirical estimation of St is conducted using firm-level productivity data to quantify how Jugaad adoption in one firm influences industry-wide efficiency. The spillover estimation employs a fixed-effects panel regression framework to ensure robust- ness.

5. Empirical Validation and Robustness Checks

5.1. Data and Methodology

The empirical analysis employs ASI data (2010–2022) covering five industries: leather, heavy metals, textiles, pharmaceuticals, and electrical equipment. The proposed function is estimated using Generalized Method of Moments (GMM), controlling for endogeneity. Instrumental variables (IVs), including regional energy prices and credit availability, are tested for exogeneity using weak-instrument tests (Stock-Yogo critical values) and Hansen J-tests. Overidentification tests are conducted to further validate IV selection, with additional discussion addressing potential reverse causality concerns.

5.2. Results and Comparative Analysis

Table 1 presents the model performance across industries.

Table 1. *Comparative Model Performance*

Model	Industry 151	Industry 251	Average R^2
Cobb-Douglas	0.85	0.78	0.72
CES	0.92	0.80	0.76
Nested Jugaad	0.98	0.95	0.88

6. Conclusion

This study presents a refined nested production function that explicitly incorporates Ju-gaad as an endogenous efficiency mechanism. The theoretical advancements include a microfounded firm optimization model, dynamic transition equation, derived elasticity conditions, and an equilibrium framework capturing industry-wide spillover effects. Em- pirical validation confirms the model's robustness, with strong policy implications for resource allocation in emerging economies. Future research should explore cross-country validation and further refinement of Jugaad measurement metrics.

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