Input substitution for sustainable industrialisation: Evidence from India

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Abstract

The transition to clean energy use in industrial production requires policy measures such as carbon taxes. However, higher prices for electricity and fossil fuels resulting from a carbon tax may adversely impact industrial performance and lead to loss in employment, especially in developing countries. In this article, I examine the possibilities for substitution between labour and fossil energy in the Indian manufacturing sector, to identify sectors where substituting labour for coal (or other fossil fuels) would increase employment and prevent any losses in industrial output from a carbon tax. Estimating the elasticity of substitution between labour and fossil energy, drawing on an industry-state-level panel dataset over the 2008-09 to 2018-19 period, I find labour and coal are substitutes in 12 of the 24 broad manufacturing sectors, while labour and electricity are complements in all sectors. Carbon taxes on coal, combined with subsidies for renewable energy, could galvanise the green energy transition in Indian manufacturing. Further policy support for specific labour-intensive sectors could spur employment creation in Indian industry, ensuring a just energy transition.

Keywords: Industrial policy, green energy transition, employment, labour-intensive manufacturing

JEL Codes: Q41, Q55, O33

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1 Introduction

An abundance of coal is known to have powered the industrial revolution in eighteenth century Britain. The low wage for workers compared to the price of coal created the necessary conditions for innovation in energy- and capital-intensive modes of production. The consequent reduction in product prices conferred Britain a competitive advantage in world markets. The decline in production costs galvanized the adoption of energy-intensive production techniques in Western Europe and the United States, boosting incomes and generating prosperity (Allen, 2011, 2006; Malanima, 2020).

In the twenty-first century, a developing country such as India, at the cusp of a green energy transition, must address the dual challenges of phasing out coal from the economy and providing quality employment to millions of its unemployed youth. While technological solutions that aim to raise the share of renewable energy sources in the energy mix are essential for a coal phase-out, a potential yet overlooked solution is to expand industrial sectors with possibilities for substitution between fossil-based energy and other factors of production such as labour.

This paper investigates possibilities for substitution between labour and different sources of energy in manufacturing sector production in India. In particular, I investigate the role of relative input prices in generating these substitution possibilities, potentially through innovation in labour-augmenting technologies rather than capital-augmenting technologies (Acemoglu, 2002). This question is pertinent in the context of climate change mitigation, where policies like carbon pricing would raise the cost of fossil energy in industrial production. If substitution possibilities exist, providing policy support to industries that have a large capacity to absorb workers, could offer a pathway towards job creation, with minimal loss of competitiveness for Indian firms, in a context of rising energy prices from a carbon tax.

I estimate the elasticity of substitution between labour and energy to assess their degree of substitutability (or complementarity) along the production isoquant, keeping the firm's level of output fixed. Specifically, I estimate elasticities between labour and fossil energy (electricity and coal), labour and biomass (charcoal and wood), as well as between different energy sources (coal and biomass) for the Indian manufacturing sector. Next, I estimate elasticities between labour and fossil energy (electricity and coal) across the broad NIC-2 digit manufacturing sectors in India. I draw on an industry-state-level panel dataset from the Annual Survey of Industries (ASI), for the 2008-09 to 2018-19 period, to estimate the elasticities of substitution.

Keeping the level of output constant is key to distinguishing between substitution effects among inputs and the total effect of rising input prices on employment and output, which may be negative.[1] By providing structural estimates of the substitution elasticities, this study complements existing reduced-form analyses, such as Abeberese (2017), who finds negative effects of higher electricity prices on firm-level output in India. I additionally estimate the effects of increases in electricity and coal prices on industrial employment and output, to corroborate the estimated substitution elasticities with the existing literature on reduced form impacts of high energy prices (Abeberese 2017).

I further explore firm-level heterogeneity in substitution effects between labour and fossil energy sources (electricity and coal), and estimate elasticities of substitution across the distribution of firms' level of employment and output. Analysing firm heterogeneity is pertinent since firms have differing capabilities for innovation and technology adoption, given differences in productivity. Thus, firms may respond differently to movements in input prices. In addition, firm size is often constrained by Indian labour laws that impose stringent conditions on formal registration of firms and on retrenchment of workers, beyond a threshold level of employment (Besley and Burgess, 2004; Nagaraj, 2004).[2] Hence, we could expect differences in substitution effects between labour and fossil energy, depending on firms' level of employment.

The results show that labour and electricity are gross complements in industrial production, with an estimated elasticity of substitution less than one, across the manufacturing sector. However, labour and coal are gross substitutes in 12 of the 24 NIC-2 digit manufacturing sectors, with estimated elasticities of substitution greater than one in these sectors. Exploring heterogeneous impacts reveals considerable potential for firms to substitute labour for coal across the firm size distribution. Results from reduced form analyses show that while electricity price increases reduce industrial employment and output, increases in coal prices have no statistically significant impact on industrial employment or output.

Therefore, carbon taxes imposed on coal are unlikely to adversely impact industrial competitiveness. Nevertheless, economy-wide carbon taxes that raise electricity tariffs would likely impose substantial burdens on consumers and industry. These results suggest an optimal policy mix to stimulate green energy transitions comprise taxes on coal, subsidies for renewable energy and additional regulatory instruments to substantially increase the share of renewables in the electricity generation mix.

This paper is structured as follows. Section 2 reviews the existing literature and section

[1] A firm's supply function $y(p)$ depends on all output and input prices. An increase in input prices may reduce firms' net supply, even as firms substitute towards relatively inexpensive inputs (Mas-Colell et al., 1995).

[2] For instance, the Industrial Disputes Act, 1947, which applies to industrial establishments with 100 or more workers, requires firm owners to take government permission to retrench any worker. Other labour laws such as the Factories Act, 1948, apply for registration of firms with certain employment thresholds in the formal sector.

3 presents a conceptual framework. Section 4 describes the data sources, section 5 outlines the empirical strategy and section 6 presents descriptive statistics. The empirical results are presented in section 7 and discussed further in section 8. Section 9 concludes the paper.

2 Literature Review

The existing literature is broadly divided into three strands. The historical literature highlights the role of input prices, in particular the relatively low price of coal, in spurring innovation in capital-augmenting technologies since the mid-eighteenth century (Allen 2011, 2006; Broadberry and Gupta 2009). Malanima (2020) further correlates the rise in living standards in Europe and the United States (i.e. the Great Divide of 1820) with an increase in energy consumption in these countries in the eighteenth century. Fernihough and O'Rourke (2021) show that European cities in proximity to coalfields experienced significant economic growth after 1750.

Kelly et al. (2023) further articulate that "cheap coal allowed the development of sophisticated metalworks industries" and the application of highly specialised mechnical skills to improve methods of production in industrialising Britain. Similarly, Jorgenson (1984) finds that technical progress in the United States in the mid-twentieth century was directed towards electricity use, with substitution away from costly labour, with simultaneous improvements in the energy efficiency of output. Popp (2002) uses US patent data from 1970-1994 to show that energy prices and the quality of existing knowledge both induced innovation in energy efficient technologies. Acemoglu (2002) and Acemoglu et al. (2014) theorise the role of input prices vis-à-vis the size of the existing market for inputs, in inducing technical change directed at specific factors of production.

The empirical literature investigates the role of energy use in industrial production. Abeberese (2017) uses firm-level data from India's Annual Survey of Industries (ASI) and finds that high electricity prices dampen output and firm productivity, by reducing machine intensity, leading to a switch away from electricity-intensive modes of production. Fried and Lagakos (2023) investigate the impact of power outages on firm performance in Sub-Saharan Africa (SSA), and conclude that elimination of electricity shortages would significantly raise labour productivity, by inducing firms to use more efficient, electricity-intensive technologies.

Similar evidence has been found for firms in Europe and the United States. Metcalf and Stock (2020) find null effects of carbon taxes on GDP growth and employment in Europe. Importantly, they do not find negative effects on economic growth, as is commonly hypothesized. Levinson (2009) find that technical advances have led to a substantial decline in manufacturing sector pollution in the United States since the late 1980s, concomitantly with an increase in industrial output. Nonetheless, Walker (2011) finds a persistent decline in manufacturing sector employment in the U.S. since the mid 1980s due to improvements in pollution regulation (via the U.S.' Clean Air Act). These studies suggest potential substitutions from labour towards capital in response to environmental regulation. In the Indian context, Harrison et al. (2019) find evidence that command-and-control (CAC) legislation in the form of Supreme Court Action Plans helped reduce air pollution in 17 Indian cities, with minimal negative effects on firm productivity. Comparing the effects of the Supreme Court regulation with an economy-wide carbon tax, their results suggest a 15-30% excise tax on coal would generate equivalent pollution reductions to the CAC legislation in Indian cities (Harrison et al. 2019).

The third strand of the literature examines elasticities of substitution between pairs of inputs in the manufacturing sector (see Russell 2020, for a comprehensive review). Papageorgiou et al. (2017) estimate the elasticity of substitution between clean and dirty energy inputs in economy-wide production for 26 countries, and find an elasticity greater than one, which indicates potential for long-run sustainable growth via input substitution in industrial production. Raval (2019) estimates the elasticity of substitution between labour and capital, accounting for biased technical change. Williams and Laumas (1981) utilise firm-level data from India's Annual Survey of Industries for 1968, to estimate elasticities of substitution between input pairs including labour-energy, capital-labour and capital-energy. They employ a demand system approach and compute elasticities by broad manufacturing sectors.

In this paper, I contribute to the existing literature by providing estimates of the elasticity of substitution between labour and fossil energy (electricity and coal) for the Indian manufacturing sector. The estimated elasticities would improve our understanding of whether input substitution between energy and labour could generate long-run industrial growth and help address the twin challenge of providing large-scale employment in a developing economy. Evidence on firm-level heterogeneity may further enable design of economic policies targeted towards small or medium-sized enterprises, which may require policy support in order to bear the costs of technology adoption.

3 Conceptual Framework

In this section, I present a conceptual framework to derive the elasticity of substitution between labour and energy, σ. Consider sectoral output Q, as a function of three inputs - capital (K), labour (L) and energy (E). We will estimate elasticities of substitution between labour and different forms of energy. Hence, energy input (E) in the production function may comprise electricity, coal or biomass (charcoal or wood).

$$Q = f(K, L, E) \tag{1}$$

We assume the production function takes the Constant Elasticity of Substitution (CES) form, as we aim to estimate an elasticity of substitution that remains constant over various input combinations, along the production isoquant.[3] The substitution parameter is represented by ρ, while the elasticity of substitution is given by $\sigma = \frac{1}{1-\rho}$.

$$Q = [K^{\rho} + (\omega_L L)^{\rho} + (\omega_E E)^{\rho}]^{\frac{1}{\rho}} \tag{2}$$

We allow for factor-augmenting technical change for labour and energy, where ω_L and ω_E represent labour- and energy-augmenting technical change, respectively. We omit the distribution parameters from the model to explicate the role of directed technical change in determining the optimal input mix. The firm maximises profits, taking product and factor prices as given, with the following profit maximisation problem:

$$max_{\{K,L,E\}} \quad \Pi = p_Q Q(K, L, E) - p_K K - p_L L - p_E E \tag{3}$$

Substituting for the production function Q in the profit maximisation problem yields the first-order conditions with respect to labour and energy:

$$\frac{\partial \Pi}{\partial L} = p_Q [K^{\rho} + (\omega_L L)^{\rho} + (\omega_E E)^{\rho}]^{\frac{1}{\rho}-1} \omega_L^{\rho} L^{\rho-1} - p_L = 0 \tag{4}$$

$$\frac{\partial \Pi}{\partial L} = p_Q [K^{\rho} + (\omega_L L)^{\rho} + (\omega_E E)^{\rho}]^{\frac{1}{\rho}-1} \omega_E^{\rho} E^{\rho-1} - p_E = 0 \tag{5}$$

The optimality condition for the labour-energy input ratio is:

$$\frac{\omega_L^{\rho} L^{\rho-1}}{\omega_E^{\rho} E^{\rho-1}} = \frac{p_L}{p_E} \tag{6}$$

Rearranging the above equation and substituting for σ yields the input ratio (L/E), in terms of input prices, factor-augmenting technical changes and the elasticity of substitution, as follows:

$$\frac{L}{E} = \left(\frac{p_L}{p_E}\right)^{-\sigma} \left(\frac{\omega_E}{\omega_L}\right)^{1-\sigma} \tag{7}$$

We estimate the Morishima elasticity of substitution, which relates the relative input

[3] As proved by Uzawa (1962) and Sato (1967), for the elasticity of substitution to remain constant along the isoquant, the production function must be of the Constant Elasticity of Substitution (CES) form (Arrow et al. 1961).

quantities to their relative prices, holding the levels of other inputs constant, for a given level of output (Morishima, 1967; Blackorby and Russell 1981; Russell 2020).

Taking the logarithm on both sides of eqn. 7, we obtain the following estimating equation:

$$ln\left(\frac{L}{E}\right) = \sigma ln\left(\frac{p_E}{p_L}\right) + (1-\sigma)\left(\frac{\omega_E}{\omega_L}\right) + \epsilon \tag{8}$$

where σ is the Morishima elasticity of substitution (MES). Given a downward-sloping production isoquant, we consider the absolute value of the elasticity, σ.

We aim to empirically estimate the Morishima elasticity of substitution between labour and energy, σ. The key challenge to identification is that the relative price of energy to labour $\left(\frac{p_E}{p_L}\right)$ may be correlated with unobserved factor-augmenting technical changes $(\frac{\omega_E}{\omega_L})$, and other unobserved productivity shocks, ϵ. To address this challenge, we draw on well-established insights from the economic history literature and argue that relative input prices not only correlate with factor-augmenting technical changes, but are the source of these productivity improvements and hence drive technical changes $(\frac{\omega_E}{\omega_L})$ (Allen, 2011, 2006; Broadberry and Gupta, 2009). Thus, we posit that factor-augmenting technical change $(\frac{\omega_E}{\omega_L})$, is a channel through which relative input prices $(\frac{p_E}{p_L})$ impact the optimal input ratio $(\frac{L}{E})$, along the production isoquant.

Robert Allen's concept of a "high-wage economy" contends that relative prices drive technical change, which is directed towards factors of production that are in abundant supply and have relatively low costs (Allen 2011). This argument is formalised in Acemoglu (2002), who theoretically shows the role of the "price" vs. "market size" effects in determining factor-augmenting technical change. Directed technical change is further distinguished from sector-wide or economy-wide productivity shocks, which would uniformly raise total factor productivity (TFP) for all firms in a sector, or for all sectors in an economy (Acemoglu et al. 2014; Acemoglu, 2002).

We argue that directed technical change is the primary channel through which substitution possibilities between two factors of production in a sector are generated. Given that directed technical change is a potential determinant of the elasticity of substitution, unobserved technical changes thus do not pose the problem of omitted variables bias, but would be "bad controls" if explicitly included in the regressions (Angrist and Pischke, 2008). Nonetheless, the argument of technical change being a mechanism for generating substitution possibilities is rather conceptual than fully rigorous, and we are unable to empirically test this hypothesis due to difficulties in measurement of technical change.

4 Data Sources

Data at the firm level are drawn from the Government of India's Annual Survey of Industries (ASI) database, for the 2008-09 to 2018-19 period. The ASI is conducted annually for registered establishments and records measures of input use, input prices and output levels of the establishment over the preceding year of the survey. While the census of large firms (firms with 200 or more workers) is conducted each year,[4] smaller firms with less than 200 workers are sampled from the sampling frame of establishments in the Economic Census. Hence, smaller firms are not tracked over time. We construct (i) a pooled cross-sectional dataset at the firm level for the 2008-09 to 2018-19 period, and (ii) a panel dataset at the level of industry[5] (NIC-5 digit) by state by region (rural/urban). The panel dataset yields a sample of 107,709 observations.

The survey reports input quantities for electricity, coal and other energy sources such as charcoal and wood, with corresponding product codes drawn from the National Product Classification for the Manufacturing Sector (2004 and 2011). Biomass largely corresponds to wood-based forest products within the category of "forestry and logging products", and includes fuelwood (in the form of logs, twigs etc.) as well as wood-based charcoal. Coal and electricity usgae is directly reported, although the sources of electricity (whether drawn from thermal power or renewable energy) are not recorded in the survey.

While other fossil fuels such as petrol and diesel may have important substitution effects with electricity (for example, through the use of diesel generators) or biomass, data for these are too sparse to be considered for detailed econometric analysis, and hence are excluded from estimation. Similarly, we are unable to estimate elasticities of substitution for firms in the informal sector due to lack of data on input prices and input quantities in the National Sample Survey Organisation (NSSO)'s Enterprise Survey for the informal sector.[6].

Identification of the elasticities requires the ratio of input prices to be plausibly exogenous, and hence be uncorrelated with unobserved determinants (ϵ) of the input ratio. To address potential endogeneity concerns, we compute average prices for electricity at the level of NIC-3 digit industry by state, region (rural/urban) and year. Electricity tariffs for industries are set by state distribution companies (discoms) in India, with a block tariff structure based on the estimated electricity demand. Since these do not necessarily vary over time

[4]The census sector of the Annual Survey of Industries entails additional formal requirements, detailed by the Ministry of Statistics and Programme Implementation (MOSPI), Government of India (accessible here).

[5]We utilise National Industrial Classification (NIC) codes, 2008, provided by MOSPI, Government of India.

[6]The NSS Enterprise Surveys, conducted quinquennially for informal sector firms, record expenditures on fuels and other inputs, but do not contain data on firm-level input prices or specific fuels used (such as electricity, coal, biomass etc.).

within a particular state, we rely on tariff data reported in the ASI survey to reflect *de facto* prices faced by firms across industries and obtain sufficient price variation to estimate the elasticities.

Constructing average prices by industry reduces the potential correlation between a firm's electricity demand and the reported tariff, and circumvents issues of price-setting behaviour by large firms in certain industries. The average industry-level price of electricity can then be considered plausibly exogenous to the firm's electricity demand. Further, our panel is constructed at the detailed NIC-5 digit level, while average electricity prices are at the aggregated NIC-3 digit industry level, which likely mitigates concerns of endogeneity of electricity prices at the industry-level.

We further construct average prices for the remaining fuels (coal, charcoal and wood) by state, region (rural/urban) and year, as we do not expect prices for these fuels to be systematically correlated with industry-level characteristics. Prices for these fuels are likely determined in competitive markets. As the ASI data do not contain identifying information for districts, we are unable to exploit price variation across districts within states for these fuels.

The wage rate for labour is computed as the ratio of total wages (or salaries) to the total number of mandays paid for by the firm, which effectively yields the wage rate per manday in the firm. From firm-level wage rates, we construct average wage rates per manday by NIC-3 digit industry code, state, region (rural/urban) and year, to circumvent possible endogeneity between wage rates and labour demand by the firm. Finally, the total output of a firm equals the total monetary value (in Indian Rupees, INR) of all products and by-products produced by the firm, including production subsidies received from the government, income from services (industrial or non-industrial) and receipts from electricity generation and sale. It additionally includes the sale value of goods that are sold in the same condition as were purchased by the firm.[7]

5 Empirical Strategy

5.1 Elasticity of Substitution

To empirically estimate the elasticity of substitution between labour and energy (where energy comprises electricity, coal or biomass), we utilise the panel dataset (at the level of NIC-5 digit industry by state, region and year). We apply the OLS with fixed effects within-

[7]Firm-level output is computed based on the tabulation programme provided in the ASI database documentation.

estimator and estimate eqn. 8 as follows:

$$ln\left(\frac{L}{E}\right)_{isrt} = \alpha_{isr} + \gamma_t + \sigma_n ln\left(\frac{p_E}{p_L}\right)_{msrt} + (1-\sigma)\left(\frac{\omega_E}{\omega_L}\right) + \epsilon_{isrt} \tag{9}$$

where σ_n is the Morishima elasticity of substitution (MES) for the (i) overall manufacturing sector, or the (ii) NIC-2 digit industry n, α_{isr} is the industry (NIC-5 digit) by state by region (rural/urban) fixed effect and γ_t is the year fixed effect. The independent variable of interest, $ln\left(\frac{p_E}{p_L}\right)_{msrt}$, is the relative input price of energy to labour for the NIC-3 digit industry m, state s, region r and year t. The dependent variable, $ln\left(\frac{L}{E}\right)_{isrt}$, is the ratio of input quantities of labour to energy for the NIC-3 digit industry m, state s, region r and year t.[8]

The panel data regressions allow for arbitrary forms of directed technical change (ω_L and ω_E), including economy-wide technical change or industry- or firm-specific technical change. This flexibility in modelling technical change allows for potentially differing levels of technology adoption across firms within an industry or across industries. While the fixed effects estimator eliminates sources of time-invariant unobserved heterogeneity, we do not expect the estimator to eliminate sources of directed technical change due to the dynamic nature of innovation and technological improvements.

In subsequent specifications, we interact the independent variable (the input price ratio) with industry codes at the NIC-2 digit level to obtain distinct elasticities of substitution between labour and energy for these broad manufacturing sectors. We next interact the input price ratio with firm size categories[9] and firm output categories[10] to assess possible heterogeneity in the substitution elasticities along these dimensions. Lastly, we interact the input price ratio with both firm size and output categories, as well as the broad NIC-2 digit sectors, to identify specific industries and types of firms which may exhibit greater possibilities for substitution between labour and energy in industrial production.

5.2 The effects of energy prices on industrial performance

We additionally estimate the reduced form effect of energy prices on industrial employment and output. While the elasticity of substitution captures the *substitution effect* between

[8]For alternative input pairs (for e.g. two different energy sources such as coal and biomass), the corresponding input prices and quantity combinations will be used in the regressions.

[9]We create the following size bins based on the total number of workers in a firm: 0-10, 11-20, 21-50, 51-100, 101-500 and 501+ workers.

[10]Firms are classified as having low, medium or high output levels, based on thresholds of total annual output. Firms are categorised as having "low" output if total annual output is less than Rs. 88.86 lacs (US$ 107,260), "medium" output if total annual output is between Rs. 88.86 lacs and Rs. 48.52 crores (US$ 5.86 million), and "high" output if total annual output exceeds Rs. 48.52 crores (US$ 5.86 million).

two inputs, holding output (and other inputs) constant, the reduced form effect of energy prices on employment captures the combined effect of (i) substitution among inputs along the isoquant and (ii) possible reductions in total output due to input price increases (the *output effect*), and hence reduced demand for labour. Analysing both substitution and output effects of energy price increases is highly relevant in the context of climate policy for developing countries, which may impact industrial competitiveness and export performance.

Drawing on the industry-state-level panel dataset, we estimate the effect of electricity and coal prices on industrial employment and output, with the following estimating equation:

$$lnY_{isrt} = \alpha_{isr} + \gamma_t + lnP_{msrt} + \epsilon_{isrt} \tag{10}$$

where the outcome variable, lnY_{isrt} is the logarithm of (i) employment and (ii) output in NIC-5 digit industry i, state s, region (rural/urban) r and year t, and the independent variable lnP_{msrt} is the average price of electricity for NIC-3 digit industry m, state s, region r and year t. In regressions with coal prices, lnP_{srt} is the average price of coal for state s, region r and year t (see section 4 for details). The α_{isr} is the NIC-5 digit industry-state-region fixed effect and γ_t is the year fixed effect, while ϵ_{isrt} is a normally distributed error term.

To conduct robustness checks, we additionally estimate the reduced form effects of energy prices on industrial employment and output, using the pooled cross-sectional dataset at the firm level. In the pooled cross-sectional regressions, we introduce dummy variables for industry (NIC-5 digit), state, region and year, to capture the effects of time-invariant unobserved heterogeneity at the industry level and year-specific trends.

6 Descriptive Statistics

We present summary statistics for input usage and input prices, drawing on the panel dataset of industry-state-level observations, for the years 2008-09 and 2018-19 in Table 1. We additionally present statistics on total output and employment for the NIC-2 digit sectors in Appendix Table 13. The panel sample contains on average 8,500 - 10,500 industry-state-level observations per year. While most industries directly use electricity in production, only around 10% of industries directly use coal in production. Biomass is sparsely used in industrial production. We observe only around 50 - 200 industry-state-level observations per year with reported use of biomass.

Table 1: Summary statistics for input use and input prices at the state-industry level

	2008-09								
	N	N (Value > 0)	Mean	Std. Dev.	p25	p75	p90	p99	Max
Employment	8,490	8,484	657	4,090	21	387	1,180	8,051	236,645
Qty. Electricity (kWh)	8,490	8,478	2.2e+07	2.0e+08	9.7e+04	4.2e+06	2.1e+07	3.6e+08	8.9e+09
Qty. Coal (tonne)	8,490	1,254	7,822	133680	0	0	302	116621	5.9e+06
Qty. Charcoal (kg)	8,490	54	53,526	3.1e+06	0	0	0	0	2.8e+08
Qty. Wood (cubic meter)	8,490	52	131	4,941	0	0	0	0	380,367
Wage rate per manday worked	8,486	8,485	178	95	1.3e+02	201	261	546	2,179
Avg. price of Electricity	8,486	8,480	3.9	1	3.2	4.6	5.3	6.3	14
Avg. price of Coal	8,372	8,372	5,837	2,765	4.6e+03	6,418	7,526	23,981	23,981
Avg. price of Charcoal	5,804	5,804	530	1,385	11	55	3,206	6,018	6,018
Avg. price of Wood	5,643	5,643	3,963	3,633	1.0e+03	5,123	9,919	14,159	14,159
N	8,490								

	2018-19								
	N	N (Value > 0)	Mean	Std. Dev.	p25	p75	p90	p99	Max
Employment	10,553	10,401	864	4,362	25	515	1,643	11,796	232,902
Qty. Electricity (kWh)	10,553	10,544	2.5e+07	2.0e+08	1.5e+05	6.9e+06	3.1e+07	3.9e+08	1.0e+10
Qty. Coal (tonne)	10,553	1,471	12,980	364776	0	0	358	164699	3.5e+07
Qty. Charcoal (kg)	10,553	79	36,801	1.4e+06	0	0	0	0	1.2e+08
Qty. Wood (cubic meter)	10,553	179	121013	8.3e+06	0	0	0	2,011	7.8e+08
Wage rate per manday worked	10,521	10,521	433	162	3.4e+02	482	600	1,016	4,441
Avg. price of Electricity	10,552	10,552	7.1	1.4	6.3	8	8.8	10	29
Avg. price of Coal	10,274	10,274	8,667	3,610	6.5e+03	9,782	11,073	28,460	28,460
Avg. price of Charcoal	7,099	7,099	50	62	19	48	106	371	371
Avg. price of Wood	9,774	9,774	5,454	2,688	3.9e+03	6,953	9,101	12,981	12,981
N	10,553								

Note: All input prices including the wage rate for labour are reported in Indian Rupees (INR) per unit input.

Mean daily wages[11] have risen from Rs. 178 in 2008-09 to Rs. 433 in 2018-19. At the upper tails of the wage distributions, we observe daily wage rates of up to Rs. 2,179 in 2008-09 and up to Rs. 4,441 in 2018-19. Average reported electricity prices have ranged from Rs. 3.90 per kWh to Rs. 7.10 per kWh over the 2008-09 to 2018-19 period. Maximum electricity prices have ranged from Rs. 14 per kWh in 2008-09 to Rs. 29 per kWh in 2018-19, across industries and states. Similarly, average coal prices have risen from Rs. 5,837 per tonne in 2008-09 to Rs. 8,667 per tonne in 2018-19. Coal prices have exhibited a large dispersion within survey years, with the maximum reported coal prices ranging from Rs. 23,981 per tonne in 2008-09 to Rs. 28,460 per tonne in 2018-19. However, coal prices do not appear to have significantly risen over the last decade.

7 Results

We present three sets of empirical results. First, we estimate elasticities of substitution between labour and energy (including electricity, coal and biomass), and between coal and biomass. Next, we estimate elasticities of substitution for the NIC-2 digit manufacturing sectors, and analyse heterogeneity in the elasticities of substitution by firm size (employment and output). Further, we interact firm size with NIC-2 digit sectors to identify industries and types of firms which may exhibit greater possibilities for substitution between energy and labour. Lastly, we estimate the reduced-form effects of electricity and coal prices on industrial employment and output.

7.1 Elasticities of Substitution

The Morishima Elasticity of Substitution (MES) reflects possibilities for substitution between two inputs along the production isoquant, holding the level of output and other inputs constant. An elasticity value greater than one suggests the two inputs are gross substitutes. In this case, an increase in the relative price of energy to labour would induce firms to substitute labour for energy, and increase their labour input, without a reduction in output. On the contrary, an elasticity value less than one suggests the two inputs are complements or "poor substitutes", and a rise in the relative price of energy to labour would not induce firms to substitute labour for energy. Instead, increases in energy prices would reduce both output and employment in that sector.

The estimated elasticities of substitution between labour and energy (including electricity, coal and biomass) are displayed in Tables 2 - 5. The elasticity of substitution between coal

[11] Formally, we compute the wage per manday worked in a firm.

and biomass (charcoal and wood) is displayed in Table 6. The regressions show a range of specifications, including OLS with fixed effects using the industry-state-level panel dataset and robustness checks using alternative state- and industry-level fixed effects.

The estimated elasticities of substitution between labour and energy are smaller than one for most energy sources, including electricity, coal, and biomass, in most regression specifications. The elasticity coefficients are statistically significant at the 95% confidence level in all regressions. The elasticity of substitution between labour and electricity ranges from 0.34 - 0.5 across specifications, while the elasticity between labour and coal ranges from 0.45 - 1.13 across specifications. This suggests relatively greater substitution possibilities between labour and coal in production.

Table 2: Elasticity of substitution between Labour and Electricity

log(Qty. ratio - Labour to Electricity)	(1)	(2)	(3)	(4)
log(Price ratio - Electricity to Labour)	0.429***	0.467***	0.507***	0.336***
	(0.012)	(0.015)	(0.013)	(0.017)
Urban Area		0.223***	0.0927***	
		(0.009)	(0.007)	
N	107,709	107,709	107,709	107,709
R^2	0.017	0.068	0.426	0.017
Year Dummies	Yes	Yes	Yes	No
State Dummies	No	Yes	Yes	No
Rural/Urban Dummies	No	Yes	Yes	No
NIC-5 digit Dummies	No	No	Yes	No
Year FE	No	No	No	Yes
State × Rural/Urban × NIC-5 digit FE	No	No	No	Yes

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Constant term suppressed.

The elasticity of substitution between labour and biomass is below one, ranging from 0.27 - 0.95 for labour and charcoal, and from 0.57 - 0.86 for labour and wood. The sample sizes for these regressions are considerably smaller due to the limited use of biomass in industrial production.

The elasticity of substitution between coal and biomass is less precisely estimated, with relatively low sample sizes for these regressions. Estimated elasticities range from 0.41 - 0.96 for coal and charcoal, and from -0.25 to 1.28 for coal and wood. The estimated elasticities are not statistically significant at the 95% confidence level.

Table 3: Elasticity of substitution between Labour and Coal

log(Qty. ratio - Labour to Coal)	(1)	(2)	(3)	(4)
log(Price ratio - Coal to Labour)	1.134***	0.758***	0.449***	0.454***
	(0.058)	(0.078)	(0.069)	(0.072)
Urban Area		0.732***	0.311***	
		(0.042)	(0.036)	
N	15,488	15,488	15,488	15,488
R^2	0.026	0.076	0.447	009
Year Dummies	Yes	Yes	Yes	No
State Dummies	No	Yes	Yes	No
Rural/Urban Dummies	No	Yes	Yes	No
NIC-5 digit Dummies	No	No	Yes	No
Year FE	No	No	No	Yes
State × Rural/Urban × NIC-5 digit FE	No	No	No	Yes

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Constant term suppressed.

Table 4: Elasticity of substitution between Labour and Charcoal

log(Qty. ratio - Labour to Charcoal)	(1)	(2)	(3)	(4)
log(Price ratio - Charcoal to Labour)	0.947***	0.704***	0.364**	0.267*
	(0.174)	(0.168)	(0.124)	(0.109)
Urban Area		0.217	0.618*	
		(0.288)	(0.266)	
N	779	779	779	779
R^2	0.073	0.253	0.666	0.041
Year Dummies	Yes	Yes	Yes	No
State Dummies	No	Yes	Yes	No
Rural/Urban Dummies	No	Yes	Yes	No
NIC-5 digit Dummies	No	No	Yes	No
Year FE	No	No	No	Yes
State × Rural/Urban × NIC-5 digit FE	No	No	No	Yes

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Constant term suppressed.

On the whole, there are limited possibilities for substitution between labour and energy in the manufacturing sector. However, average substitution effects for the entire manufacturing

Table 5: Elasticity of substitution between Labour and Wood

log(Qty. ratio - Labour to Wood)	(1)	(2)	(3)	(4)
log(Price ratio - Wood to Labour)	0.823***	0.569***	0.858***	0.858***
	(0.144)	(0.150)	(0.138)	(0.160)
Urban Area		0.561**	0.0199	
		(0.188)	(0.186)	
N	852	852	852	852
R^2	0.039	0.171	0.529	0.095
Year Dummies	Yes	Yes	Yes	No
State Dummies	No	Yes	Yes	No
Rural/Urban Dummies	No	Yes	Yes	No
NIC-5 digit Dummies	No	No	Yes	No
Year FE	No	No	No	Yes
State × Rural/Urban × NIC-5 digit FE	No	No	No	Yes

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Constant term suppressed.

Table 6: Elasticity of substitution between Coal and Biomass

	log(Quantity ratios)			
	Coal to Charcoal		Coal to Wood	
log(Price ratio - Charcoal to Coal)	0.961***	0.414*		
	(0.217)	(0.217)		
log(Price ratio - Wood to Coal)			1.278*	-0.252
			(0.736)	(0.621)
N	290	290	73	73
R^2	0.117	0.130	0.050	0.063
Year Dummies	Yes	No	Yes	No
Year FE	No	Yes	No	Yes
State × Rural/Urban × NIC-5 digit FE	No	Yes	No	Yes

Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Constant term suppressed.

sector mask significant heterogeneity in elasticities of substitution across sectors. Next, we investigate elasticities of substitution between labour and fossil energy (electricity and coal) at the NIC-2 digit industry level. Substitution elasticities between labour and electricity by NIC-2 digit sectors are displayed in Appendix Table 14, while elasticities of substitution between labour and coal by NIC-2 digit sectors are displayed in Table 7.

Estimated elasticities of substitution between labour and electricity are below one for all NIC-2 digit manufacturing sectors (Appendix Table 14). For the manufacture of basic metals, the elasticity is close to one (0.9). Nevertheless, the results show that labour and electricity are gross complements in production, highlighting the indispensability of electricity use in the manufacturing sector.

Estimated elasticities of substitution between labour and coal show disparate effects across sectors (Table 7). Elasticities are greater than one for 12 of the 24 NIC-2 digit manufacturing sectors, with statistically significant coefficients at the 99% confidence level. Elasticities greater than one suggests labour and coal are gross substitutes in several industries. These include labour-intensive industries such as the manufacture of tobacco products, leather products, wearing apparel, computer, electronic and optical products, and electrical equipment, and key metalworks industries such as fabricated metal products, machinery and equipment (n.e.c.), motor vehicles and other transport equipment, other manufacturing, and the repair and installation of machinery and equipment.

Therefore, an increase in coal prices would not reduce employment in these sectors, as technological advancements would lead to substitution towards labour, replacing coal, and maintain the level of industrial output.

Table 7: Elasticity of substitution between Labour and Coal by NIC - 2 digit industry

NIC-2 digit industry	σ
Manufacture of food products	0.817***
	(0.056)
Manufacture of beverages	0.524***
	(0.066)
Manufacture of tobacco products	1.435***
	(0.066)
Manufacture of textiles	0.793***
	(0.057)
Manufacture of wearing apparel	1.552***
	(0.092)
Manufacture of leather and related products	1.278***
	(0.066)
Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.723*** (0.068)
Manufacture of paper and paper products	0.130*
	(0.057)

NIC-2 digit industry	σ
Printing and reproduction of recorded media	1.559***
	(0.250)
Manufacture of coke and refined petroleum products	0.893***
	(0.102)
Manufacture of chemicals and chemical products	0.473***
	(0.062)
Manufacture of pharmaceuticals, medicinal chemical and botanical products	0.945***
	(0.068)
Manufacture of rubber and plastics products	0.881***
	(0.060)
Manufacture of other non-metallic mineral products	0.305***
	(0.056)
Manufacture of basic metals	0.619***
	(0.055)
Manufacture of fabricated metal products, except machinery and equipment	1.200***
	(0.059)
Manufacture of computer, electronic and optical products	1.471***
	(0.155)
Manufacture of electrical equipment	1.365***
	(0.082)
Manufacture of machinery and equipment n.e.c.	1.194***
	(0.058)
Manufacture of motor vehicles, trailers and semi-trailers	1.978***
	(0.090)
Manufacture of other transport equipment	1.633***
	(0.087)
Manufacture of furniture	0.993***
	(0.155)
Other manufacturing	1.625***
	(0.115)
Repair and installation of machinery and equipment	1.209***
	(0.140)
N	15,488
R^2	0.234

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Constant term suppressed. Year dummy variables included.

7.2 Firm Heterogeneity: Elasticities of Substitution by Firm Size

We next examine heterogeneity in substitution effects between labour and fossil energy (electricity and coal) by firm size based on levels of employment and output, across the NIC-2 digit sectors. Firms' substitution capabilities between labour and energy may differ both across and within sectors. In particular, larger firms may have higher rates of technology adoption and the necessary resources to invest in research and development for technological advancements within industries. While we lack data on firms' R&D capabilities, we examine elasticities of substitution between labour and energy along two dimensions of firm size: employment and total output.

We create (i) employment categories based on the number of workers employed at a firm annually, and (ii) output categories (low, medium and high output) based on threshold levels of firm-level total annual output. We consider the following employment categories: 0-10, 11-20, 21-50, 51-100, 101-500 and 501+ workers. Firm-level output categories are as follows: "low" output if total annual output is less than Rs. 88.86 lacs (US$ 107,260), "medium" output if total annual output is between Rs. 88.86 lacs and Rs. 48.52 crores (US$ 5.86 million), and "high" output if total annual output exceeds Rs. 48.52 crores (US$ 5.86 million).

Elasticities of substitution by firm employment categories are displayed in Table 8 and elasticities by firm output categories are presented in Table 9. Elasticities of susbtitution by energy source (electricity/coal), firm size (employment/output) and across NIC 2-digit sectors, are presented in Appendix Tables 15 - 18.

Elasticities of substitution between labour and electricity, and between labour and coal, exceed one in most firm employment categories (Table 8), which suggests significant possibilities for substitution between labour and energy, across the firm size distribution in the manufacturing sector. However, elasticities of substitution between labour and energy are below one in most output categories (Table 9), which suggests firms with high levels of output on average do not exhibit sizeable substitution effects between labour and energy vis-à-vis firms with relatively low levels of output.

Next, we interact firm size and output categories with the NIC-2 digit manufacturing sectors to further examine heterogeneity in elasticities of substitution between labour and fossil energy (Appendix Tables 15 - 18). The results show significant variation in elasticities of substitution across firm employment categories and manufacturing sectors. Elasticities of substitution between labour and electricity exceed one in small and large firms in several sectors, including food products; beverages; textiles; wood products; paper products; rubber and plastics; and basic metals (Appendix Table 15). However, substitution effects between labour and coal are driven by specific types of firms in certain sectors (Appendix Table 16). These include, for example, firms with over 20 employees in the tobacco industry; large firms with over 100 employees in the computer and electronics industry; and large firms in motor vehicles manufacturing and manufacture of transport equipment.

Table 8: Firm Heterogeneity: Elasticities by employment categories

	log(Quantity ratios)			
	Labour to Electricity		Labour to Coal	
	(1)	(2)	(3)	(4)
log(Price ratio - Elec. to labour)	1.087***			
	(0.011)			
Interaction: Price ratio × size bins				
log(Price ratio - Elec. to labour)				
× Bin 1: 0-10 Workers		1.185***		
		(0.012)		
× Bin 2: 11-20 Workers		1.146***		
		(0.012)		
× Bin 3: 21-50 Workers		1.104***		
		(0.011)		
× Bin 4: 51-100 Workers		1.070***		
		(0.011)		
× Bin 5: 101-500 Workers		1.116***		
		(0.011)		
× Bin 6: 501+ Workers		1.136***		
		(0.011)		
log(Price ratio - Coal to labour)			1.051***	
			(0.049)	
Interaction: Price ratio × size categories				
log(Price ratio - Coal to labour)				
× Bin 1: 0-10 Workers				1.042***
				(0.049)
× Bin 2: 11-20 Workers				0.997***
				(0.049)
× Bin 3: 21-50 Workers				1.047***
				(0.049)
× Bin 4: 51-100 Workers				1.077***
				(0.049)
× Bin 5: 101-500 Workers				1.091***
				(0.049)
× Bin 6: 501+ Workers				1.265***
				(0.051)
N	472,736	472,736	46,832	46,832
R^2	0.129	0.135	0.141	0.153

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
All regressions include year, state and sector (rural/urban) dummies.

Table 9: Firm Heterogeneity: Elasticities by output categories

	log(Quantity ratios)			
	Labour to Electricity		Labour to Coal	
	(1)	(2)	(3)	(4)
log(Price ratio - Elec. to labour)	1.087***			
	(0.011)			
Interaction: Price ratio × output categories				
log(Price ratio - Elec. to labour)				
× Bin 1: Low Output		0.565***		
		(0.011)		
× Bin 2: Medium Output		0.765***		
		(0.011)		
× Bin 3: High Output		0.942***		
		(0.011)		
log(Price ratio - Coal to labour)			1.051***	
			(0.049)	
Interaction: Price ratio × output categories				
log(Price ratio - Coal to labour)				
× Bin 1: Low Output				1.146***
				(0.048)
× Bin 2: Medium Output				0.967***
				(0.047)
× Bin 3: High Output				0.849***
				(0.048)
N	472,736	472,736	46,832	46,832
R^2	0.129	0.191	0.141	0.165

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
All regressions include year, state and sector (rural/urban) dummies.

Considering heterogeneity along the distribution of firm output, we find limited substitution possibilities between labour and energy. Labour and electricity are gross substitutes (with elasticities greater than one) in some large firms (with high output levels) in the manufacture of textiles; paper products; rubber and plastics; and basic metals (Appendix Table 17). Labour and coal are gross substitutes (with elasticities greater than one) in all firms in the tobacco industry, and in manufacture of computers and electronic products (Appendix Table 18). Firms with low levels of output also exhibit substitution possibilities between labour and coal in manufacture of furniture and other transport equipment. Lastly, firms with high levels of output exhibit substitution possibilities between labour and coal in the manufacture of motor vehicles; other transport equipment; machinery n.e.c., and in the repair and installation of machinery (Appendix Table 18).

7.3 The impact of coal and electricity prices on manufacturing sector performance

Thus far, we have estimated the elasticity of substitution between labour and energy in production, holding sectoral output fixed. Next, we estimate the reduced form effect of energy prices on industrial employment and output, drawing on the NIC-5 digit industry-state-level panel dataset, for the 2008-09 to 2018-19 period. The reduced form effects reflect the combined *substitution* and *output* effects of increases in input prices on firm output and input demand (see section 3). Hence, we complement analysis of substitution effects among production inputs, with the combined effect of energy prices on output and input use. Specifically, we investigate the effects of increases in electricity and coal prices on industrial employment and output (see Tables 10 and 11).

The results suggest increases in electricity prices significantly reduce industrial employment and output across the manufacturing sector, with coefficients statistically significant at the 99% confidence level. In particular, a 1% increase in electricity prices reduces industrial employment by 0.2 - 1.3%, and industrial output by 0.3 - 1.5%, on average, for the manufacturing sector. These results are similar to those obtained in Abeberese (2017),[12] who finds negative effects of electricity prices on firm-level output and productivity in Indian manufacturing, drawing on the Annual Survey of Industries (ASI) database. Similarly, Fried and Lagakos (2023) observe that electricity is a key input in the manufacturing sector in developing countries and an important determinant of firm-level productivity growth in African and Asian industries.

While higher electricity prices dampen industrial output and employment, we do not find any statistically significant impacts of higher coal prices on industrial employment or output across the manufacturing sector. The reduced form results corroborate evidence from the estimated elasticities of substitution, which suggest that electricity is a gross complement to labour across the manufacturing sector, whereas coal is a gross substitute in around half of the NIC-2 digit sectors and gross complement in other sectors (Table 7). Given coal is a gross

[12]Drawing on the same database (ASI), Abeberese (2017) constructs a shift-share instrument to measure the effect of electricity prices on firm-level output and productivity. My reduced form estimates of the effects of electricity prices on industrial output are in a similar range as those of the instrumental variable (IV) specifications in Abeberese (2017).

substitute for labour in some key industries, we do not find statistically significant reductions in industrial output or employment in the overall manufacturing sector. These reduced form results alleviate concerns of a potential loss in employment and industrial competitiveness due to future introductions of carbon taxes and resulting increases in coal prices.

The differential effects of increases in coal vs. electricity prices on industrial performance also suggest a potentially significant role for substitution among energy sources for power generation. Given electricity is a key production input in all sectors (with an elasticity of substitution between labour and electricity less than one, Appendix Table 14), whereas labour and coal are substitutes in at least half of the broad NIC-2 digit manufacturing sectors, substitution between coal and renewable energy for electricity generation may be decisive to galvanise a clean energy transition.

While a broad-based carbon tax on fossil sources may potentially deplete industrial output (for instance via increases in electricity prices), carbon taxes imposed on coal, combined with subsidies for renewable energy at the source of electricity generation, may generate the necessary price signals to stimulate clean power generation.[13] We test potential substitution effects between coal and electricity by estimating the effects of coal prices on electricity demand among manufacturing industries. We find that increases in coal prices have no statistically significant impact on electricity use in industries, while coal and electricity have negative own-price elasticities (Table 12). We also find similar patterns among a sub-sample of industries that utilise both coal and electricity in production.[14] While the ASI database does not contain information on the source of electricity generation or on use of renewable energy, our empirical results suggest possible substitution between coal and other sources of power generation within the manufacturing sector.

[13]The Government of India has targeted achieving 450 GW of installed renewables capacity (excluding large hydropower plants) by 2030 (PIB, 2021). Ahluwalia and Patel (2022) estimate that this will imply about 28-30% of electricity generation from solar and wind power by 2030.

[14]These results are available upon request.

Table 10: The impacts of coal and electricity prices on industrial employment

log(Qty. Labour)	(1)	(2)	(3)	(4)	(5)$^{\zeta}$	(6)	(7)	(8)	(9)	(10)$^{\xi}$
log(Coal price)	-0.0285	0.0285	0.0423	0.00676	-0.0191					
	(0.020)	(0.024)	(0.023)	(0.016)	(0.057)					
log(Electricity price)						-0.246***	-1.262***	-0.950***	-0.206***	-0.207***
						(0.025)	(0.038)	(0.034)	(0.031)	(0.031)
N	104,996	104,996	104,996	104,996	15,488	107,826	107,826	107,826	107,826	107,714
R^2	0.003	0.087	0.325	0.013	0.013	0.003	0.099	0.328	0.013	0.013
Year Dummies	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No
State Dummies	No	Yes	Yes	No	No	No	Yes	Yes	No	No
Rural/Urban Dummies	No	Yes	Yes	No	No	No	Yes	Yes	No	No
NIC-5 digit Dummies	No	No	Yes	No	No	No	No	Yes	No	No
Year FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes
State × Rural/Urban × NIC-5 digit FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Constant term suppressed.

ζ This regression is conditioned on positive coal use in the respective industry-state-sector (rural/urban) combinations.

ζ This regression is conditioned on positive electricity consumption in the respective industry-state-sector (rural/urban) combinations.

Table 11: The impacts of coal and electricity prices on sectoral output

log(Output)	(1)	(2)	(3)	(4)	(5)$^{\zeta}$	(6)	(7)	(8)	(9)	(10)$^{\xi}$
log(Coal price)	-0.0815***	-0.00828	0.00910	0.00584	-0.0660					
	(0.023)	(0.029)	(0.026)	(0.020)	(0.057)					
log(Electricity price)						-0.615***	-1.481***	-1.104***	-0.327***	-0.328***
						(0.028)	(0.043)	(0.038)	(0.035)	(0.035)
N	104,795	104,795	104,795	104,795	15,490	107,617	107,617	107,617	107,617	107,504
R^2	0.012	0.095	0.351	0.040	0.077	0.017	0.106	0.354	0.041	0.041
Year Dummies	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No
State Dummies	No	Yes	Yes	No	No	No	Yes	Yes	No	No
Rural/Urban Dummies	No	Yes	Yes	No	No	No	Yes	Yes	No	No
NIC-5 digit Dummies	No	No	Yes	No	No	No	No	Yes	No	No
Year FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes
State × Rural/Urban × NIC-5 digit FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Constant term suppressed.

ζ This regression is conditioned on positive coal use in the respective industry-state-sector (rural/urban) combinations.

ζ This regression is conditioned on positive electricity consumption in the respective industry-state-sector (rural/urban) combinations.

Table 12: The effects of energy prices on substitution between coal and electricity

	log(Qty. Electricity)		log(Qty. Coal)
	(1)	(2)	(3)
log(Coal price)	-0.0116		-0.693***
	(0.023)		(0.114)
log(Electricity price)		-0.601***	
		(0.040)	
Observations	105,372	108,232	15,493
R^2	0.017	0.020	0.010

Robust standard errors in parentheses. Constant term suppressed.
All regression specifications include year fixed effects and state by sector (rural/urban) by NIC-5 digit industry code fixed effects.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

8 Discussion

Given significant substitution possibilities between labour and fossil energy in the Indian manufacturing sector, there is a substantial role for economic policy to expand sectors in which labour can be substituted for coal in production, to increase industrial output and employment. Industrial policies aimed at industrial expansion, while promoting the use of clean energy in manufacturing, depend critically on the estimated elasticities of substitution between labour and energy, across the manufacturing sector. In this section, we address potential identification concerns and discuss limitations of the analysis.

The empirical analysis utilises a panel dataset at the industry-state level and a pooled cross-sectional dataset at the firm level, for the 2008-09 to 2018-19 period. While the panel data regressions account for unobserved heterogeneity through inclusion of state, industry and year fixed effects, the pooled OLS regressions at the firm-level potentially suffer from omitted variables bias. In particular, we observe estimated elasticities of substitution from the panel dataset are significantly smaller than one, whereas several of the estimated elasticities at the firm level exceed one. We would expect panel data regressions estimated via OLS with fixed effects to counter the attenuation bias generated by omitted variables and therefore generate more accurate estimates of the elasticity of substitution. However, since we lack panel data at the firm-level for the Indian manufacturing sector, we are unable to test for potential omitted variables bias.

Alternatively, we would expect larger elasticities of substitution using firm-level data than industry-level data, since there are potentially greater possibilities for input substitution within specific firms in an industry, relative to the entire industry. In the industry-state-level panel dataset, we aggregate input quantities and average input prices across all firms in a sector, which may lead to underestimation of the elasticities of substitution at the sector level, compared to the firm level elasticities.

We hypothesised that directed technical change is likely a prominent driver of substitution possibilities between labour and energy, drawing on historical examples from the British Industrial Revolution (Allen, 2011). Specifically, we expect changes in relative prices for inputs to drive factor-biased technological change, and impact the optimal input mix in firms, through adoption of labour- or energy-intensive modes of production. However, we are unable to empirically test this hypothesis, due to difficulties in the accurate measurement of innovation and factor-augmenting technical change.[15]

9 Conclusion

The industrial revolution occurred in eighteenth century Britain largely on account of an abundant supply of cheap coal, which created incentives for innovation in capital- and energy-intensive modes of production (Allen, 2011). In the twenty-first century, the green energy transition needed to mitigate climate change, requires a complete phaseout of coal from the economy. In developing countries such as India, a clean energy transition must be accompanied by an increase in employment, particularly in labour-intensive manufacturing sectors. The elasticity of substitution between labour and fossil energy is decisive to assess whether labour can be substituted for coal in Indian industry, without a reduction in industrial output.

In this study, I estimated the elasticity of substitution between labour and key energy sources including electricity and coal, across the Indian manufacturing sector. I further analysed heterogeneity in substitution effects among inputs across industries and the firm size distribution. The results show that labour and electricity are strong complements in all industries. However, labour and coal are substitutes in at least half of the broad NIC-2 digit manufacturing sectors, including in key metalworks industries. Finally, I estimate the reduced form effects of energy prices on industrial performance and find that coal prices have no statistically significant impact on industrial employment or output, while increases in electricity prices reduce industrial output. A substantial increase in the share of renewable energy in the electricity generation mix, enabled through taxes on coal and subsidies for

[15] For instance, Aghion et al. (2015) follow the Olley-Pakes method and estimate total factor productivity (or economy-wide innovation) as a residual of the production function.

renewable energy, would galvanise the green energy transition, while mitigating any output losses in Indian industry.

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Appendix

Table 13: Statistics for Employment and Output by NIC-2 digit sectors, 2008-09 to 2018-19

Industry	2008-09		2018-19	
(NIC-2 digit)	Employment	Output (Rs.)	Employment	Output (Rs.)
Food products (10)	705,607	5.7e+11	948,241	1.3e+12
Beverages (11)	73,695	1.3e+11	121,550	3.0e+11
Tobacco products (12)	361,482	7.1e+10	377,790	1.4e+11
Textiles (13)	871,801	2.4e+11	1,074,608	4.8e+11
Wearing apparel (14)	476,518	2.4e+10	868,517	4.9e+10
Leather products (15)	144,707	2.6e+10	277,984	4.5e+10
Wood products (16)	24,545	1.8e+10	38,155	3.7e+10
Paper products (17)	104,221	1.4e+11	144,097	3.5e+11
Printing etc. (18)	35,907	1.7e+10	52,939	3.6e+10
Coke, petroleum etc. (19)	71,982	2.8e+12	101,090	1.8e+12
Chemicals etc. (20)	279,300	1.0e+12	490,884	1.6e+12
Pharmaceuticals (21)	152,370	1.0e+11	385,597	1.7e+11
Rubber and plastics (22)	176,757	2.0e+11	418,098	3.6e+11
Non-metallic products (23)	283,781	3.1e+11	471,504	7.3e+11
Basic metals (24)	518,887	9.1e+11	720,650	2.4e+12
Fabricated metals etc. (25)	206,238	1.4e+11	310,837	3.5e+11
Computers, electronics etc. (26)	101,303	3.1e+11	151,092	8.7e+11
Electrical equipment (27)	182,383	2.2e+11	365,959	5.6e+11
Machinery & equipment n.e.c. (28)	218,633	3.6e+11	458,795	8.5e+11
Motor vehicles etc. (29)	290,421	5.2e+11	736,603	2.4e+12
Other transport equipment (30)	140,291	2.9e+11	256,031	7.1e+11
Furniture (31)	18,427	1.4e+10	44,621	3.9e+10
Other manufacturing (32)	128,001	9.0e+10	286,429	3.5e+11
Repair of machinery etc. (33)	11,754	2.8e+10	20,192	2.4e+10
All Manufacturing	232,459	3.6e+11	380,094	6.7e+11

Table 14: Elasticity of substitution between Labour and Electricity by NIC - 2 digit industry

NIC-2 digit industry	σ
Manufacture of food products	0.582***
	(0.012)
Manufacture of beverages	0.557***
	(0.013)
Manufacture of tobacco products	0.140***
	(0.021)
Manufacture of textiles	0.543***
	(0.013)
Manufacture of wearing apparel	0.235***
	(0.014)
Manufacture of leather and related products	0.355***
	(0.014)
Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.422***
	(0.014)
Manufacture of paper and paper products	0.642***
	(0.013)
Printing and reproduction of recorded media	0.436***
	(0.013)
Manufacture of coke and refined petroleum products	0.566***
	(0.014)
Manufacture of chemicals and chemical products	0.593***
	(0.012)
Manufacture of pharmaceuticals, medicinal chemical and botanical products	0.528***
	(0.013)
Manufacture of rubber and plastics products	0.685***
	(0.012)
Manufacture of other non-metallic mineral products	0.535***
	(0.013)
Manufacture of basic metals	0.908***
	(0.013)
Manufacture of fabricated metal products, except machinery and equipment	0.449***
	(0.012)
Manufacture of computer, electronic and optical products	0.338***
	(0.012)
Manufacture of electrical equipment	0.439***
	(0.012)
Manufacture of machinery and equipment n.e.c.	0.394***
	(0.012)

NIC-2 digit industry	σ
Manufacture of motor vehicles, trailers and semi-trailers	0.440***
	(0.012)
Manufacture of other transport equipment	0.420***
	(0.012)
Manufacture of furniture	0.362***
	(0.015)
Other manufacturing	0.343***
	(0.013)
Repair and installation of machinery and equipment	0.208***
	(0.013)
N	107,709
R^2	0.170

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Constant term suppressed. Year dummy variables included.

Table 15: Elasticities of substitution between labour and electricity (σ), by firm size bins and NIC-2 digit sectors

NIC-2 digit sector (Code)	Firm Size Bins (No. of Workers) 0-10	11-20	21-50	51-100	101-500	501+
Food products	1.213***	1.160***	1.096***	1.033***	0.991***	0.920***
(10)	(0.011)	(0.012)	(0.012)	(0.012)	(0.011)	(0.013)
Beverages	1.263***	1.080***	1.023***	1.005***	1.012***	0.976***
(11)	(0.013)	(0.017)	(0.017)	(0.016)	(0.013)	(0.016)
Tobacco products	0.485***	0.482***	0.238***	-0.0538	-0.221***	-0.437***
(12)	(0.019)	(0.025)	(0.025)	(0.030)	(0.023)	(0.036)
Textiles	1.013***	1.061***	1.080***	1.113***	1.196***	1.180***
(13)	(0.012)	(0.012)	(0.012)	(0.012)	(0.011)	(0.012)
Wearing apparel	0.882***	0.822***	0.768***	0.718***	0.669***	0.638***
(14)	(0.013)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)
Leather products etc.	1.143***	1.020***	0.920***	0.833***	0.745***	0.704***
(15)	(0.014)	(0.015)	(0.014)	(0.014)	(0.012)	(0.013)
Wood products etc.	1.026***	1.094***	1.069***	1.032***	1.035***	1.033***
(16)	(0.012)	(0.015)	(0.016)	(0.020)	(0.020)	(0.029)
Paper products etc.	1.043***	1.040***	1.083***	1.225***	1.255***	1.363***
(17)	(0.012)	(0.013)	(0.014)	(0.016)	(0.014)	(0.025)
Printing etc.	0.913***	0.955***	0.989***	0.986***	0.966***	1.004***
(18)	(0.012)	(0.013)	(0.012)	(0.013)	(0.013)	(0.035)
Coke, petroleum etc.	0.931***	0.939***	0.935***	0.957***	1.032***	1.198***
(19)	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)	(0.028)
Chemicals etc.	0.971***	0.951***	0.946***	0.978***	1.006***	1.206***
(20)	(0.011)	(0.012)	(0.012)	(0.013)	(0.012)	(0.015)
Pharmaceuticals etc.	0.901***	0.907***	0.974***	1.027***	1.065***	1.112***
(21)	(0.012)	(0.013)	(0.012)	(0.012)	(0.011)	(0.012)
Rubber and plastics etc.	1.237***	1.221***	1.211***	1.209***	1.173***	1.173***
(22)	(0.012)	(0.012)	(0.012)	(0.012)	(0.011)	(0.013)

	0-10	11-20	21-50	51-100	101-500	501+
Non-metallic minerals etc.	1.078***	0.915***	0.649***	0.477***	0.927***	1.400***
(23)	(0.012)	(0.013)	(0.013)	(0.015)	(0.013)	(0.016)
Basic metals	1.201***	1.345***	1.409***	1.383***	1.372***	1.447***
(24)	(0.012)	(0.013)	(0.013)	(0.013)	(0.011)	(0.013)
Fabricated metals etc.	0.976***	0.942***	0.925***	0.914***	0.912***	0.848***
(25)	(0.011)	(0.011)	(0.012)	(0.012)	(0.011)	(0.015)
Computers, electronics etc.	0.821***	0.767***	0.808***	0.796***	0.803***	0.888***
(26)	(0.012)	(0.013)	(0.012)	(0.012)	(0.012)	(0.016)
Electrical equipment	0.936***	0.882***	0.867***	0.880***	0.897***	0.950***
(27)	(0.011)	(0.012)	(0.012)	(0.012)	(0.011)	(0.013)
Machinery & equipment n.e.c.	0.872***	0.823***	0.841***	0.853***	0.890***	0.953***
(28)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)
Motor vehicles etc.	0.927***	0.910***	0.935***	0.952***	0.948***	0.984***
(29)	(0.012)	(0.012)	(0.012)	(0.012)	(0.010)	(0.011)
Other transport equipment	0.956***	0.946***	0.917***	0.911***	0.913***	0.941***
(30)	(0.012)	(0.013)	(0.014)	(0.014)	(0.011)	(0.012)
Furniture	0.902***	0.848***	0.840***	0.840***	0.833***	0.948***
(31)	(0.013)	(0.017)	(0.018)	(0.018)	(0.015)	(0.037)
Other manufacturing	0.910***	0.873***	0.846***	0.840***	0.757***	0.669***
(32)	(0.013)	(0.014)	(0.013)	(0.013)	(0.011)	(0.013)
Repair of machinery etc.	0.804***	0.689***	0.654***	0.665***	0.595***	0.380***
(33)	(0.013)	(0.017)	(0.015)	(0.021)	(0.019)	(0.060)
N	472,736					
R^2	0.319					

Robust standard errors in parentheses. The regression includes state, sector (rural/urban) and year dummies.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 16: Elasticities of substitution between labour and coal (σ), by firm size bins and NIC-2 digit sectors

NIC-2 digit sector (Code)	Firm Size Bins (No. of Workers) 0-10	11-20	21-50	51-100	101-500	501+
Food products	0.303***	0.187***	0.204***	0.227***	0.313***	0.554***
(10)	(0.047)	(0.045)	(0.041)	(0.040)	(0.038)	(0.053)
Beverages	0.126	-0.222*	-0.125	0.105	0.284***	0.647***
(11)	(0.123)	(0.112)	(0.082)	(0.086)	(0.053)	(0.103)
Tobacco products	0.975***	0.793***	1.005***	1.171***	1.252***	1.671***
(12)	(0.044)	(0.068)	(0.064)	(0.062)	(0.046)	(0.042)
Textiles	0.139**	0.101	0.152**	0.177***	0.258***	0.800***
(13)	(0.051)	(0.053)	(0.047)	(0.045)	(0.041)	(0.047)
Wearing apparel	0.586***	0.491**	0.413*	0.437**	0.574***	0.970***
(14)	(0.147)	(0.162)	(0.208)	(0.156)	(0.070)	(0.088)
Leather products etc.	0.516***	0.552***	0.601***	0.572***	0.697***	0.950***
(15)	(0.076)	(0.084)	(0.077)	(0.068)	(0.052)	(0.057)
Wood products etc.	0.467***	0.209**	0.283***	0.476***	0.493***	0.639***
(16)	(0.091)	(0.078)	(0.081)	(0.094)	(0.067)	(0.075)
Paper products etc.	-0.0157	-0.0183	0.0121	0.0510	-0.0386	-0.249***
(17)	(0.084)	(0.077)	(0.058)	(0.052)	(0.045)	(0.045)
Printing etc.	1.252***	1.267***	0.926**	0	0.473***	0.967***
(18)	(0.157)	(0.076)	(0.353)	(.)	(0.126)	(0.048)
Coke, petroleum etc.	0.429***	0.286*	0.566***	0.566***	0.557**	0.325
(19)	(0.076)	(0.128)	(0.164)	(0.149)	(0.175)	(0.303)
Chemicals etc.	0.160**	0.270***	0.301***	0.291***	0.103*	0.0494
(20)	(0.051)	(0.067)	(0.051)	(0.056)	(0.048)	(0.057)
Pharmaceuticals etc.	0.397***	0.313**	0.447***	0.413***	0.435***	0.571***
(21)	(0.070)	(0.116)	(0.066)	(0.061)	(0.050)	(0.063)
Rubber and plastics etc.	0.440***	0.337***	0.467***	0.396***	0.499***	0.491***
(22)	(0.059)	(0.072)	(0.059)	(0.069)	(0.049)	(0.063)

	0-10	11-20	21-50	51-100	101-500	501+
Non-metallic minerals etc.	-0.00620	0.196***	0.322***	0.354***	0.312***	-0.319***
(23)	(0.043)	(0.042)	(0.041)	(0.040)	(0.041)	(0.045)
Basic metals	0.232***	0.220***	0.121**	0.104*	0.274***	0.107*
(24)	(0.041)	(0.043)	(0.044)	(0.046)	(0.044)	(0.053)
Fabricated metals etc.	0.514***	0.427***	0.517***	0.521***	0.819***	0.862***
(25)	(0.044)	(0.052)	(0.053)	(0.086)	(0.065)	(0.097)
Computers, electronics etc.	0	1.158***	0.687***	0	1.193***	1.979***
(26)	(.)	(0.113)	(0.125)	(.)	(0.141)	(0.601)
Electrical equipment	0.500***	0.741***	0.498***	0.900***	0.989***	0.954***
(27)	(0.078)	(0.113)	(0.088)	(0.149)	(0.168)	(0.117)
Machinery n.e.c.	0.436***	0.465***	0.518***	0.718***	0.897***	1.233***
(28)	(0.045)	(0.052)	(0.059)	(0.076)	(0.061)	(0.065)
Motor vehicles etc.	0.461***	0.348***	0.610***	0.799***	0.931***	2.013***
(29)	(0.070)	(0.093)	(0.160)	(0.113)	(0.105)	(0.186)
Other transport equipment	0.817***	1.252***	0.908***	0.698**	1.177***	1.720***
(30)	(0.099)	(0.094)	(0.123)	(0.224)	(0.110)	(0.111)
Furniture	0.612*	0.321*	0.336	0.603***	-0.243***	0
(31)	(0.268)	(0.163)	(0.195)	(0.178)	(0.046)	(.)
Other manufacturing	0.552***	0.980***	0.848***	0.683*	0.903***	0.541***
(32)	(0.105)	(0.208)	(0.170)	(0.269)	(0.120)	(0.102)
Repair of machinery etc.	0.938***	0.518***	1.048***	0	2.604***	1.358***
(33)	(0.150)	(0.061)	(0.279)	(.)	(0.091)	(0.311)
Observations	46,832					
R^2	0.351					

Robust standard errors in parentheses. The regression includes state, sector (rural/urban) and year dummies.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 17: Elasticities of substitution between labour and electricity (σ), by firm output bins and NIC-2 digit sectors

NIC-2 digit sector	Firm Output Bins		
(Code)	Low Output	Medium Output	High Output
Food products	0.639***	0.860***	0.946***
(10)	(0.011)	(0.011)	(0.010)
Beverages	0.969***	0.781***	0.854***
(11)	(0.013)	(0.012)	(0.012)
Tobacco products	-0.499***	-0.0979***	0.416***
(12)	(0.018)	(0.019)	(0.029)
Textiles	0.583***	0.877***	1.065***
(13)	(0.012)	(0.010)	(0.011)
Wearing apparel	0.414***	0.468***	0.522***
(14)	(0.012)	(0.010)	(0.011)
Leather products etc.	0.657***	0.616***	0.637***
(15)	(0.015)	(0.011)	(0.012)
Wood products etc.	0.652***	0.874***	0.944***
(16)	(0.012)	(0.012)	(0.022)
Paper products etc.	0.651***	0.852***	1.172***
(17)	(0.013)	(0.011)	(0.013)
Printing etc.	0.542***	0.750***	0.894***
(18)	(0.012)	(0.011)	(0.013)
Coke, petroleum etc.	0.611***	0.706***	0.873***
(19)	(0.016)	(0.012)	(0.012)
Chemicals etc.	0.448***	0.709***	0.999***
(20)	(0.012)	(0.010)	(0.011)
Pharmaceuticals etc.	0.533***	0.737***	0.920***
(21)	(0.013)	(0.010)	(0.010)
Rubber and plastics etc.	0.808***	0.988***	1.041***
(22)	(0.012)	(0.011)	(0.011)
Non-metallic minerals etc.	0.399***	0.669***	1.210***
(23)	(0.011)	(0.011)	(0.012)
Basic metals	0.694***	1.054***	1.261***
(24)	(0.012)	(0.011)	(0.011)
Fabricated metals etc.	0.624***	0.697***	0.813***
(25)	(0.011)	(0.010)	(0.011)
Computers, electronics etc.	0.479***	0.559***	0.694***
(26)	(0.013)	(0.010)	(0.011)
Electrical equipment	0.568***	0.641***	0.771***
(27)	(0.012)	(0.010)	(0.010)

	Low Output	Medium Output	High Output
Machinery n.e.c.	0.546***	0.614***	0.754***
(28)	(0.010)	(0.010)	(0.010)
Motor vehicles etc.	0.576***	0.697***	0.791***
(29)	(0.012)	(0.010)	(0.010)
Other transport equipment	0.600***	0.696***	0.749***
(30)	(0.013)	(0.011)	(0.011)
Furniture	0.542***	0.645***	0.740***
(31)	(0.013)	(0.012)	(0.017)
Other manufacturing	0.526***	0.586***	0.599***
(32)	(0.013)	(0.011)	(0.011)
Repair of machinery etc.	0.478***	0.455***	0.543***
(33)	(0.013)	(0.013)	(0.020)
N	472,736		
R^2	0.344		

Robust standard errors in parentheses. The regression includes state, sector (rural/urban) and year dummies. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 18: Elasticities of substitution between labour and coal (σ), by firm output bins and NIC-2 digit sectors

NIC-2 digit sector	Firm Output Bins		
(Code)	Low Output	Medium Output	High Output
Food products	0.585***	0.257***	0.362***
(10)	(0.053)	(0.037)	(0.042)
Beverages	0.714***	0.212***	0.231***
(11)	(0.146)	(0.058)	(0.055)
Tobacco products	1.253***	1.253***	1.087***
(12)	(0.041)	(0.041)	(0.063)
Textiles	0.400***	0.219***	0.623***
(13)	(0.056)	(0.041)	(0.044)
Wearing apparel	0.558**	0.681***	0.729***
(14)	(0.198)	(0.068)	(0.086)
Leather products etc.	0.608***	0.734***	0.742***
(15)	(0.137)	(0.049)	(0.051)
Wood products etc.	0.725***	0.367***	0.543***
(16)	(0.103)	(0.053)	(0.068)
Paper products etc.	0.368***	0.121**	-0.195***
(17)	(0.109)	(0.044)	(0.043)
Printing etc.	1.114***	1.057***	0.562***
(18)	(0.047)	(0.190)	(0.164)
Coke, petroleum etc.	0.529***	0.452***	0.410**
(19)	(0.158)	(0.070)	(0.154)
Chemicals etc.	0.419***	0.297***	0.0179
(20)	(0.067)	(0.046)	(0.046)
Pharmaceuticals etc.	0.575***	0.475***	0.350***
(21)	(0.098)	(0.052)	(0.049)
Rubber and plastics etc.	0.662***	0.436***	0.463***
(22)	(0.076)	(0.046)	(0.051)
Non-metallic minerals etc.	0.425***	0.305***	-0.332***
(23)	(0.040)	(0.040)	(0.042)
Basic metals	0.411***	0.264***	0.0666
(24)	(0.042)	(0.040)	(0.043)
Fabricated metals etc.	0.666***	0.495***	0.632***
(25)	(0.044)	(0.045)	(0.068)
Computers, electronics etc.	1.480***	1.015***	1.948**
(26)	(0.257)	(0.089)	(0.594)
Electrical equipment	0.620***	0.628***	0.959***
(27)	(0.114)	(0.064)	(0.112)

	Low Output	Medium Output	High Output
Machinery n.e.c.	0.664***	0.509***	1.160***
(28)	(0.047)	(0.043)	(0.074)
Motor vehicles etc.	0.628***	0.646***	1.612***
(29)	(0.086)	(0.065)	(0.164)
Other transport equipment	1.116***	0.980***	1.405***
(30)	(0.086)	(0.086)	(0.117)
Furniture	1.444***	0.361***	0.137**
(31)	(0.341)	(0.102)	(0.048)
Other manufacturing	0.686***	0.801***	0.800*
(32)	(0.114)	(0.080)	(0.369)
Repair of machinery etc.	0.903***	0.848***	1.438***
(33)	(0.183)	(0.137)	(0.296)
N	46,832		
R^2	0.348		

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$