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The impact of credit constraints on total-factor energy efficiency: Evidence from manufacturing firms

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Take-home message

- **Research question:**
Do credit constraints affect total-factor energy efficiency (TFEE) of firms, and how much?
- **Data:**
5,154 manufacturing firms from 39 countries.
- **Methods:**
 - TFEE is derived from data envelopment analysis (DEA).
 - An endogenous switching model is applied to control for endogeneity, selection bias, and firm heterogeneity.
 - Results are aggregated to sectoral level and compared with those in previous studies
- **Key results:**
 - Average TFEE score differs for credit-constrained and credit-unconstrained firms.
 - TFEE of constrained firms would increase by lifting credit constraints.
 - The role of credit constraints differs across sectors and firms.
- **Policy implications:**
Sectoral loan guarantee programs and credit supply could improve energy efficiency of firms.

Motivation

- Energy efficiency measures are of great interests of industrial firms
 - Reduce costs and GHG emissions without output losses.
- However, market barriers, such as lack of financing (or credit Constraints), may prevent firms from adopting cost-effective energy efficiency technologies (Earnhart and Segerson, 2012; Andersen, 2017; Tian and Lin, 2019; Zhang et al., 2019).
- Previous studies have largely overlooked the variation of energy efficiencies across firms within a given sector as well as the variation across industrial sectors. This motivate this study.

A large firm-level database

Data on 5,154 manufacturing firms from 39 countries collected by the World Bank Enterprise Surveys (Enterprise Surveys, 2020)

- All sample countries are from Central and Eastern Europe and Central Asia, except for two African countries
- Some sectors are combined due to few observations and similar production processes
- Top five industrial sectors in terms of the number of firms (>8%)
 1. Food and tobacco
 2. Fabricated metal products
 3. Machinery and equipment
 4. Non-metallic mineral products, and
 5. Garments

Table 1. Distribution of firms across manufacturing sectors.

ISIC code	Description	No.	in %
15	Food and including tobacco (16)	1,171	22.7 %
17	Textiles	247	4.79 %
18	Garments	442	8.58 %
19	Leather	121	2.35 %
20	Wood	209	4.06 %
21	Paper	75	1.46 %
22	Publishing, printing, and recorded media	106	2.06 %
23	Refined petroleum product and including chemicals (24)	217	4.21 %
25	Plastics & rubber	350	6.79 %
26	Non metallic mineral products	493	9.57 %
27	Basic metals	96	1.86 %
28	Fabricated metal products	630	12.2 %
29	Machinery and equipment	502	9.74 %
30	Office machinery and including electronics (31), communication (32), and precision instruments (33)	196	3.80 %
34	Motor vehicles and including other transport equipment (35)	93	1.80 %
36	Furniture	206	4.00 %
	Sum	5,154	100 %

Note: ISIC refers to the International Standard of Industrial Classification codes.

Table 2. Definitions of variables and descriptive statistics.

Variable	Definition	Mean	SD	Min	Max
Credit-Constrained	Dummy that equals 1 for constrained firms and 0 otherwise	0.182	0.386	0	1
R&D	Dummy that equals 1 for firms with R&D investment and 0 otherwise	0.245	0.430	0	1
Sales	Sales in euro and logarithmic scale	13.86	2.23	8.956	21.25
Capital-Labor	Capital labor ratio, see text	9.571	2.131	1.237	18.96
Export	Dummy that equals 1 for exporters and 0 otherwise	0.402	0.490	0	1
Foreign-Ownership	Dummy that equals 1 for firms with foreign ownership and 0 otherwise	0.096	0.294	0	1
Age	Firm age in years and logarithmic scale	2.887	0.664	0.693	4.477
Firm-Size (base, small firms with 5-19 employees)					
Size-Medium	Dummy that equals 1 for medium-sized firms (the number of employees between 20 and 99) and 0 otherwise	0.354	0.478	0	1
Size-Large	Dummy that equals 1 for large firms (the number of employees over 100) and 0 otherwise	0.224	0.417	0	1

Measuring TFEE

- TFEE (percentage points) for a firm

$$TFEE(i) = \frac{\textit{Target Energy Input (i)}}{\textit{Actual Energy Input (i)}} \times 100$$

- TFEE for for an industrial sector

$$TFEE(I) = \frac{\sum_{i \in I} \textit{Target Energy Input (i)}}{\sum_{i \in I} \textit{Actual Energy Input (i)}} \times 100$$

Calculated TFEE

Four groups of firms:

- Firms whose loan applications were approved;
- Firms whose loan applications were rejected;
- Firms that did not apply for bank loans because “interest rates were not favorable” or because they “did not think it would be approved.”
- Firms that did not apply for bank loans because application procedures were complex,” “collateral requirements were too high,” or “the size of loan and the maturity were insufficient.”

Table 4. TFEE scores by manufacturing sector.

ISIC code	Whole sample	Credit-constrained firms	Credit-unconstrained firms
15	57.71	57.37	57.77
17	56.97	56.66	57.04
18	60.61	61.26	60.49
19	57.67	56.54	57.97
20	56.54	56.65	56.52
21	55.95	52.17	57.24
22	60.14	57.58	60.59
23	57.48	56.98	57.60
25	56.70	54.39	57.33
26	55.36	54.65	55.58
27	56.73	54.00	57.36
28	60.93	62.16	60.65
29	61.40	63.07	61.09
30	59.89	62.02	59.54
34	59.38	59.60	59.33
36	58.80	57.99	59.04
Grand mean	58.49	58.11	58.57

Note: See [Table 1](#) for the descriptions of the ISIC codes.

Endogenous switching model

- Regression equation

$$TFEE_i = a_0 + a_1 CreditConstrained_i + \beta' X_i + \sum_{k=1}^n d_k Country_{k,i} + \sum_{k=1}^o e_k Sector_{k,i} + u_i \quad (3)$$

- A probit model for determining the factors influencing credit constraint conditions

$$CreditConstrained_i = \begin{cases} 1 & \text{if } C_i^* > 0 \\ 0 & \text{if } C_i^* \leq 0 \end{cases}$$

$$\Pr(CreditConstrained) = \varphi(Y_i)$$

- Reduced equations to regress TFEE

$$Y_i = \delta' Z_i + v_i$$

$$TFEE_{1i} = \beta'_1 X_{1i} + \varepsilon_{1i} \quad \text{if } CreditConstrained_i = 1$$

$$TFEE_{2i} = \beta'_2 X_{2i} + \varepsilon_{2i} \quad \text{if } CreditConstrained_i = 0$$

Estimated results of the endogenous switching model

Table 5. Maximum likelihood estimates of the endogenous switching model.

Variable	Criteria equation	TFEE equations	
	(Credit-Constrained)	Constrained firms	Unconstrained firms
	Estimate	Estimate	Estimate
Intercept	1.182 ^{***} [0.1972]	43.1656 ^{***} [2.5829]	27.4447 ^{***} [1.1796]
R&D	0.1583 ^{***} [0.0489]	0.2215 [0.6985]	-1.2276 ^{***} [0.3096]
Sales	-0.1281 ^{***} [0.0171]	2.3243 ^{***} [0.2562]	3.6795 ^{***} [0.1007]
Capital-Labor	-0.0375 ^{***} [0.0131]	-2.3371 ^{***} [0.1657]	-1.6663 ^{***} [0.0803]
Export	-0.1244 ^{**} [0.0503]	-2.7433 ^{***} [0.7048]	-0.3371 [0.3067]
Foreign-Ownership	0.097 [0.0735]	0.6098 [1.0402]	-2.128 ^{***} [0.4507]
Age	-0.0686 ^{**} [0.0315]	-0.7261 [*] [0.4242]	0.0543 [0.2032]
Size-Medium	0.3316 ^{***} [0.0511]	0.6864 [0.7775]	-3.747 ^{***} [0.3092]
Size-Large	0.6899 ^{***} [0.0699]	2.7658 ^{**} [1.1607]	-5.9506 ^{***} [0.4139]
Instrument			
Lease	0.0947 ^{***} [0.0324]		
Informal-Competition	0.0287 [0.0428]		
Sigma		10.9449 ^{***} [0.6825]	8.5521 ^{***} [0.1204]
Rho		0.8723 ^{***} [0.0318]	-0.8438 ^{***} [0.0157]
Country effects	Yes	Yes	Yes
Sector effects	Yes	Yes	Yes
Observations	5,154	939	4,215

Note: ^{***}, ^{**}, and ^{*} indicate significance at the 0.01, 0.05, and 0.1 level, respectively. Standard errors are in brackets.

Counterfactual analysis

The counterfactual analysis is used to evaluate the extent to which credit constraints affect TFEE, measured by **treatment effects** by the differences between actual and counterfactual expectation of TFEE.

- For credit-constrained firms, we compare
 - the conditional expectation of the actual TFEE
 - the counterfactual expectation given that credit-constrained firms had not been constrained.
- For unconstrained firms, we compare
 - the conditional expectation of the actual TFEE
 - the counterfactual expectation given that the credit unconstrained firms had not been constrained

Counterfactual analysis

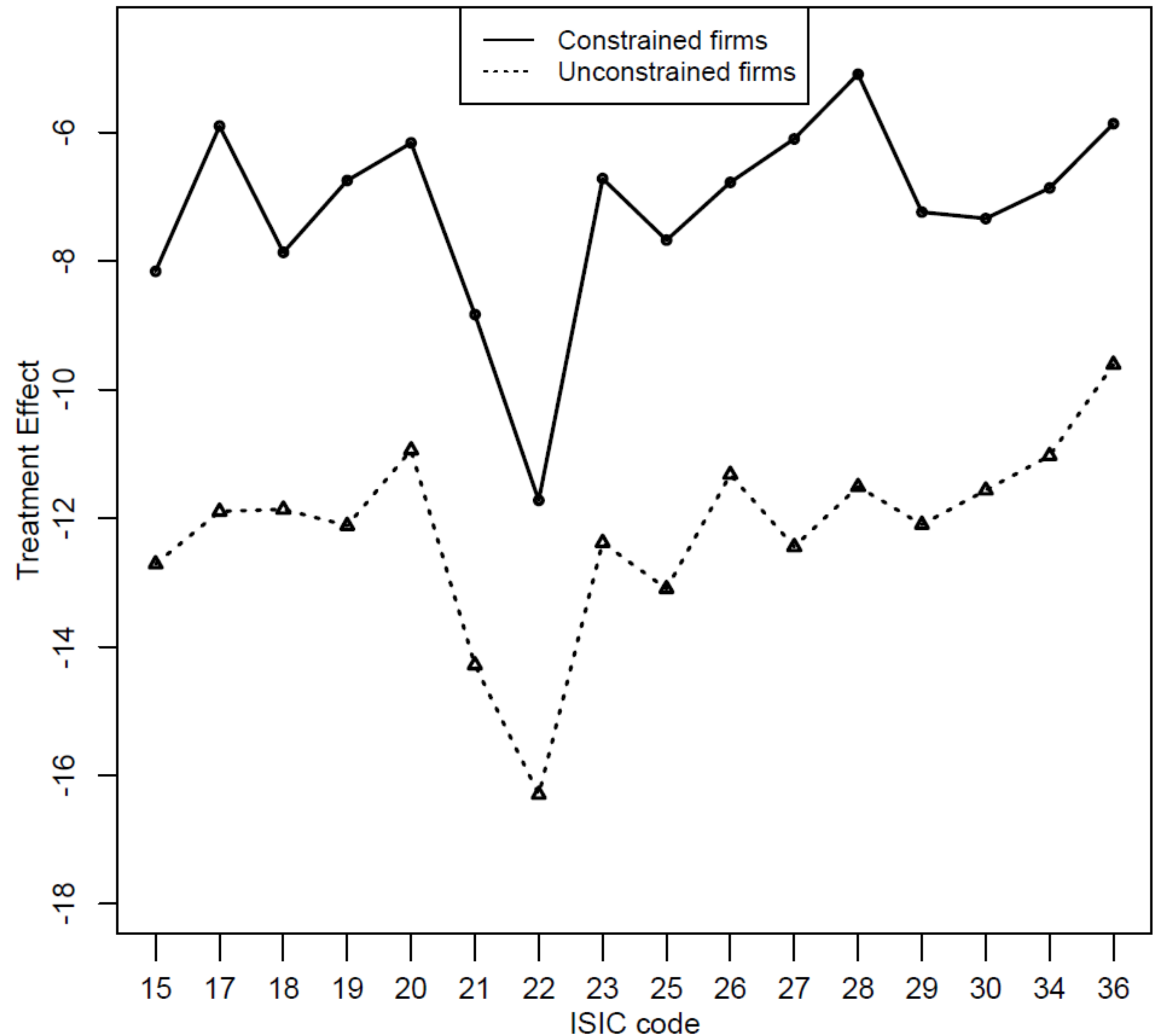
Treatment effects for credit-constrained and credit-unconstrained firms, by manufacturing sector

For the whole sample, the average treatment effect is

- -7.05 for constrained firms
- -12.09 for unconstrained firms.

For each sector as shown in the figure,

- the treatment effect of constrained firms is larger than that of unconstrained firms, indicating some common driving forces behind the credit constraints–TFEE relationship for each sector.
- ISIC 22 (Publishing, printing, and recorded media) is the most severely affected by credit constraints, followed by ISIC 21 (Paper).



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