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Mitigation options for energy-related CO_2 emissions in the Indonesian manufacturing sector

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Why mitigation

- Manufacturing sector is a major contributor to Indonesia's aggregate level of CO_2 emissions,
- Previous study on decomposition on energy-related CO_2 emissions indicated the need for emission abatement technologies in the majority of manufacturing sub-sectors in Indonesia
- The increasing trend towards coal consumption in manufacturing industry has become a major environmental concern for the country.
- A policy on fuel subsidy reduction is being implemented that can stimulate the demand for energy efficiency.

Roads to ratifying Kyoto Protocol

1992 Indonesia signed the UNFCCC
1994 Indonesia ratified the UNFCCC through Law No. 6/1994
1997 Indonesia signed the Kyoto Protocol
1998-1999 The first national communication on climate changeconvention
June 2004 The enactment of Law No.17 2004 resulted in a legal basis for ratifying the Kyoto Protocol
Dec 2004 Indonesia submitted Kyoto Protocol ratification instrument to the UN Secretary General in New York

- *a study assessing the impact on the Indonesian economy of implementing the Kyoto Protocol would be very relevant, although Indonesia has no formal commitment*
- *Indonesia's ratification of the Kyoto Protocol is expected to bring its environmental policy into greater domestic prominence*

The objectives

- The main objective: to find the most efficient mitigation scenario, defined as that which would give a specified reduction level in CO2 emissions with minimal impact on manufacturing activity.
- *In this paper: to report the initial stages of the study (estimating the impact of a carbon tax)*

Main model

1. Estimating the impact of the carbon tax

- Translog cost function

2. Investigating mitigation measures

- Clean Development Mechanisms
- Tradable permits

In this study, these mechanisms are analyzed for their effectiveness and the level of activity required to bridge the gap between the desired level of CO2 emissions and the level of CO2 emissions derived from future energy demand.

3. Energy efficiency initiatives.

Carbon tax:

- affects fuel mix and reduces fuel demand.
- the increase in energy prices as a result of the carbon tax should promote energy efficiency improvements

Adopting energy efficiency initiatives:

- would assist the sector to achieve the need for future energy demand

Translog cost function

The aggregate production function for manufacturing sub-sectors

$$Q = f[K, L, E[C, O, G, EL]]$$

The cost function takes the form

$$C = C[P_K, P_L, P_E, Q]$$

Then the aggregate energy function can be written as:

$$E = E(C, O, G, EL)$$

The energy cost function can be stated as

$$P_E = P(P_O P_C P_G P_{EL})$$

The fuel cost function of energy sub-model takes the form:

$$\ln P_E = \alpha_0 + \sum \beta_i \ln P_{Ei} + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_{Ei} P_{Ej}$$

The fuel cost share function in the cost of aggregate energy, takes the form

$$S_{Ei} = \beta_i + \sum_j \gamma_{ij} \ln P_{Ei}, \qquad i, j = O, C, G, EL$$

S_{Ei} is the cost shares of the i fuel in the costs of aggregate energy, $\sum_i S_{Ei} = 1$,

with requires the following restrictions. $\sum_i \beta_i = 1; \gamma_{ij} = \gamma_{ji}; \sum_i \gamma_{ij} = 0$

The Allen partial elasticities are given by:

$$\sigma_{ii} = (\gamma_{ii} + S_i^2 - S_i) / S_i^2 \quad ; \quad \sigma_{ij} = (\gamma_{ij} + S_i S_j) / S_i S_j, i \neq j$$

The price elasticities of demand are calculated as:

$$\varepsilon_{ii} = \sigma_{ii} \times S_i \quad ; \quad \varepsilon_{ij} = \sigma_{ij} \times S_j, i \neq j$$

The Data

- based on the annual survey of large and medium scale manufacturing industries (1980-2000).
- Database: value added, fuel expenditure and the amount of fuel used (oil, coal, natural gas, and electricity) in the two digit manufacturing sector (ISIC 31 to ISIC 39).
- Fuel shares in the manufacturing sector

		1980				2000			
Subsector	ISIC	Oil	Coal	Gas	Elect	Oil	Coal	Gas	Elect
Food	31	84.7	1.2	0.1	14.1	39.6	24.3	15.9	20.2
Textile	32	82.6	0.2	0.1	17.2	68.1	0.8	4.8	26.2
Wood	33	87.1	0.0	0.0	12.9	62.3	1.1	3.5	33.2
Paper	34	85.6	0.0	0.0	14.4	63.9	4.9	1.2	30
Chemical	35	77.1	0.1	0.2	22.6	29.3	45.6	5.6	19.4
Non-metal	36	38.6	5.1	53.1	3.2	50.4	2	27	20.5
Basic metal	37	16.8	0.9	78.0	4.4	19.3	60.6	11.6	8.6
Fab. metal	38	75.4	1.3	2.5	20.8	16.2	3.5	61.7	18.6
Total	3	55.8	2.5	31.8	9.8	45.5	0.1	11.1	43.3

Data: Level of CO2 emissions from the manufacturing sector

SECTOR	ISIC	CO_2 emissions		CO_2 emissions by fuel (%)			
		ton CO_2	%	Oil	Coal	Gas	Electricity
Food	31	12,060,371	9.64	39.71	0.60	2.15	57.54
Textile	32	21,222,932	16.96	32.67	0.70	1.38	65.25
Wood	33	5,581,965	4.46	34.55	3.38	0.49	61.59
Paper	34	21,919,945	17.52	18.18	34.80	2.58	44.44
Chemical	35	14,519,417	11.60	33.60	1.69	13.54	51.18
Non-metal	36	27,441,711	21.93	14.23	55.69	6.48	23.60
Basic metal	37	11,067,333	8.84	11.83	3.23	34.02	50.91
Fab. metal	38	10,852,148	8.67	33.09	2.07	8.00	56.83
TOTAL		125,136,383	100.00	25.11	19.30	7.62	47.97

Data constraints

- Energy prices in Indonesia may not actually reflect competitive market prices (highly regulated and might not represent the true opportunity costs of the fuel).
- Possibilities of measurement error. This could result in significant volatility estimated fuel prices.
- Whether fuel demand was actual unconstrained demand or constrained by supply availability (whether fuel demand reflected a free market mechanism).

The Results of translog model

- some of the parameter estimates are not statistically significant at 5% significance level.
- the low values of R-squared in some fuel cost share equations; lack of accuracy in the data could cause the insignificant results and small R^2s.
- the partial elasticities of energy demand could provide a relatively clear picture how fuel demand changed in response to changes in manufacturing activity.

Own price elasticities of energy demand

- Own-price elasticities are mostly negatives
- For total manufacturing sector (ISIC 3) the own price elasticities : –0.6254 for oil; -0.2517 for coal; -0.5444 for gas; and –0.9807 for electricity.
- The own price elasticities for electricity are higher, while the own price elasticities for coal relatively lower than generally found in related studies.

Table: Own price elasticities of energy demand

ISIC	Sub-sector	ε_{OO}	ε_{CC}	ε_{GG}	ε_{ELEL}
31	Food	-0.1817	0.0903	-2.1939	-0.8840
32	Textile	-0.6059	-0.2659	-1.1764	-0.3340
33	Wood	-0.1181	-1.1606	-1.3085	-0.3575
34	Paper	-0.1164	-1.5244	-1.3418	0.0158
35	Chemical	-0.2906	-0.5896	-1.1411	-0.4106
36	Non-metal	-0.1624	-0.6626	-0.5388	0.1151
37	Basic met.	-0.8484	1.0332	-0.4572	0.0098
38	Fab. metal	-0.2760	-0.4645	-0.5494	-0.1717
	Total	-0.6254	-0.2517	-0.5444	-0.9807

Cross price elasticities of energy demand

- Substitution pattern among fuels are more dominant than complementary as most of the cross price elasticities are positive.
- It is observed that oil is weakly substitutable with other fuels, except in basic metal industries. There is a tendency for oil to be substituted by gas
- Demand for oil and electricity are inelastic both to its own price changes and changes in the prices of other fuels.
- Coal showed high own price elasticities. However, changes in coal prices have no significant influence on the demand for other fuels.
- Coal and oil are substitutes, while coal and electricity tend to be complements.
- Demand for gas is relatively elastic, and it appears that gas and oil are substitutes

Table: Cross price elasticities of energy demand

Subsector ISIC	Food 31	Textile 32	Wood 33	Paper 34	Chemical 35	Non-metal 36	Basic metal 37	Fab. metal 38	Total
e_{OC}	-0.0025	0.0043	0.0060	0.0697	0.0000	-0.0418	0.1470	-0.0073	0.0514
e_{OG}	0.0083	0.0251	0.0017	0.0112	0.0895	0.2835	0.9080	0.1563	0.3180
e_{OEL}	0.1759	0.5765	0.1104	0.0356	0.2010	-0.0792	-0.2066	0.1270	0.2559
e_{CO}	-0.6220	0.3647	7.1741	5.0444	0.0177	-0.0589	4.3453	-1.0308	0.5040
e_{CG}	0.3263	-0.1352	-0.1994	-0.2044	0.2492	0.8434	1.2693	-0.2942	0.5134
e_{CEL}	0.2053	0.0364	-5.8140	-3.3157	0.3227	-0.1219	-6.6478	1.7895	-0.7657
e_{GO}	0.8436	0.7978	3.3456	1.0217	1.3832	0.1493	0.3018	1.3230	0.4187
e_{GC}	0.1343	-0.0503	-0.3230	-0.2586	0.0095	0.3155	0.0143	-0.0176	0.0690
e_{GEL}	1.2160	0.4288	-1.7141	0.5787	-0.2516	0.0740	0.1411	-0.7559	0.0567
e_{ELO}	0.8243	0.3262	0.3770	0.1429	0.4449	-0.3599	-0.2929	0.4332	1.1363
e_{ELC}	0.0039	0.0002	-0.0165	-0.1841	0.0018	-0.3933	-0.3188	0.0432	-0.3470
e_{ELG}	0.0559	0.0076	-0.0030	0.0254	-0.0360	0.6380	0.6019	-0.3047	0.1914

The Assumptions

- The estimated impact of a carbon tax is based on the (partial) price elasticities for each type of fuel calculated using the translog cost share function.
- Estimation assumes constant price elasticities, and no significant changes related to energy efficiency technologies during the period under estimation.
- Price changes resulting from a carbon tax will not change the manufacturing structure significantly.
- Carbon tax is applied on 1997 fuel prices at various rates ranging from $5 to $30 per ton of carbon
- A carbon tax of $30 is considered a high tax scenario. A higher rate would not be prudent, since the tax rate would then exceed the price of the fuel itself.

The results: impact of a carbon tax

- With a tax of $15 per ton of carbon, the percentage reduction in CO2 emissions was almost 20%.
- The impact of a carbon tax was not found to be significant in the wood, basic metal and fabricated metal sub-sectors

Table : The impact of carbon taxes on CO2 emission level

Tax level	CO2 emissions level by fuel (Mton CO2)				Total Mton CO2	% change
	Oil	Coal	Gas	Electricity		
Base	20.53	2.88	2.79	26.35	52.55	-
5	19.23	2.72	2.67	24.52	49.14	-6.5
10	17.92	2.55	2.56	22.69	45.72	-13.0
15	16.62	2.39	2.44	20.86	42.31	-19.5
20	15.31	2.23	2.32	19.03	38.89	-26.0
25	14.01	2.07	2.21	17.20	35.48	-32.5
30	12.71	1.91	2.09	15.36	32.07	-39.0

Table: The impact of carbon taxes on changes in fuel mix

		Tax rate ($ per ton carbon)		
Sub-sector	ISIC	Low ($5)	Medium ($15)	High ($30)
Food	31	-4.4	-13.1	-26.2
Textile	32	-4.2	-12.6	-25.3
Wood	33	-2.6	-7.9	-15.7
Paper	34	-10.9	-32.7	-65.4
Chemical	35	-3.3	-10.0	-19.9
Non-metal	36	-6.6	-19.8	-39.6
Basic metal	37	-0.8	-2.4	-4.7
Fab. metal	38	-2.1	-6.4	-12.7
Total	3	-6.5	-19.5	-39.0

CONCLUSION

- The imposition of a carbon tax produces a significant reduction in CO_2 emission levels. At $15 per ton of carbon, it reduced CO_2 emissions by around 20% from their 1997 level.
- The opportunities for other mitigation measures will be explored in order to meet the desired CO_2 emission level.
- Further studies will investigate energy efficiency policies that can be implemented to meet a minimum specified level of CO_2 emissions, whilst having minimal impact on future manufacturing activity.