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ASSESSING DEMAND WHEN INTRODUCING A NEW FUEL: NATURAL GAS ON JAVA

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ABSTRACT

The Indonesian Government considers investing in a gas transmission system on Java. Therfore a forecast of the demand for natural gas by the manufacturing sector is needed. However, when a new fuel is introduced, there are no historical data to assess potential demand. On the level of production processes the opportunities for natural gas are based on Net Present Value evaluations of its benefits. These evaluations are combined with subsectoral economic growth forecasts to assess future gas demand. This approach leads to a flexible forecasting tool, that can readily account for changing economic structures, as encountered by a rapid developing countries.

Keywords: energy demand, production processes, energy technology

1 INTRODUCTION

The estimation of the demand for energy by an economy or a sector of the economy can be based on either an econometric or a descriptive approach. An econometric approach tries to explain the demand for energy using (i) the level of economic activity, and (ii) relative prices [5]. A disadvantage of econometric approaches is that they require long time series, especially the more comprehensive models do. However, in developing countries, such as Indonesia, with a rapidly growing manufacturing sector where new subsectors emerge, historical data are not available. Moreover, they would be of limited use only, because of the changing economic structure.

Descriptive approaches are based on ratios that reflect the amount of energy used in production, where production at the sectoral level is usually measured by real gross value added (GVAr). One such ratio is the *energy intensity* (sometimes called energy efficiency), which is defined as the total amount of energy used divided by GVAr. Similar definitions can be given per energy carrier (oil, gas, coal, and electricity). Changes in energy intensities over time can result from many factors (technological change, increasing industrialization, more efficient use of energy, etc), and on an aggregate level these changes are hard to distinguish. Several methods to describe energy intensities, such as Laspeyres indices, try to take into account the economic structure, but require detailed information [9], [11].

Another ratio is the *energy coefficient*, defined as the relative change in energy used divided by the relative change in production. A disadvantage of the energy coefficient is that small changes in the denominator can result in large values for the energy coefficient, so usually the data over several years are combined into a moving average to stabilize the estimate. Several models have been developed to estimate long term trends in energy intensity and energy coefficients, which can be used to estimate future energy demand [1].

The main disadvantage of descriptive methods is that they do not link changes in an economy's energy ratios to changes in the energy market and in the market for other inputs, whereas the production function approach does. Changes in the structure of the economy can not be evaluated, except if formulated as Laspeyres indices.

Whatever method is used to model or describe the demand for energy, whenever a new type of fuel (in our case natural gas) is introduced, no historical data on demand are available. We could base our estimate of the demand for the new fuel on the amount of energy that would be needed to replace the amount of energy currently used. However, this estimate would not be based on economic reasoning, and would not take into account what part of the total amount of energy used in production can technically be replaced by natural gas.

Our starting point for the determination of the demand for natural gas by the manufacturing sector is the energy intensity ratio. If the information on energy utilization in production is detailed enough, the energy intensity ratio per primary fuel of a manufacturing subsector can be treated as the energy intensity of the production process itself, and represents the actual *physical intensity ratio* [10]. For our analysis of primary energy demand we prefer the physical intensity ratios over more aggregate ratios, because it allows us to identify the factors that influence the development of these ratios.

Using the information on the production process level, we determine what primary fuels are used, and which part will be replaced by natural gas. We apply a simple decision model based on microeconomic decision criteria. We distinguish two decision types: (i) decisions to convert existing plants to natural gas, and (ii) decisions choosing a fuel type for new investments. The production processes can be used to identify manufacturing subsectors according to their energy utilization. An economic growth scenario then suffices to forecast long-term demand for natural gas.

This paper is organized as follows. Section 2 describes the model used for assessment of the demand for natural gas by the manufacturing sector. In Section 3 the data collection and interpretation process for Java is described. Section 4 gives a short review of the results for the manufacturing sector on Java. Section 5 contains some concluding remarks.

2 A DESCRIPTIVE MODEL FOR PRIMARY ENERGY DEMAND

The following model describes the demand for primary fuels by the subsectors of the manufacturing sector. The demand for fuel f by subsector j in year t is denoted by $D^f_{j,t}$. It depends on the physical intensity ratio $\varepsilon^f_{j,t}$ and the real gross value added $GVAr_{j,t}$. So by definition we have

$$D^f_{j,t} = \varepsilon^f_{j,t} GVAr_{j,t} \quad , \tag{1}$$

for all $f \in F$ with F the set of all energy carriers, and $j=1,\ldots, J$ with J the number of subsectors of the manufacturing sector. So the total demand for energy carrier f in year t is, by definition

(2) $$D_t^f = \sum_{j=1}^{J} D_{j,t}^f \,.$$

The total demand for energy by subsector j in year t is defined as

(3) $$D_{j,t} = \sum_{f \in F} E^f(D_{j,t}^f),$$

where the functions E^f translate the different forms of energy into a single measure of energy; for instance, joule. The energy intensity ratio of subsector j in year t is

(4) $$\varepsilon_{j,t} = \sum_{f \in F} E^f(\varepsilon_{j,t}^f) \,.$$

The energy intensity ratio in year t for the total manufacturing sector is by definition

(5) $$\varepsilon_t = \sum_{j=1}^{J} \frac{GVAr_{j,t}}{GVAr_t} \varepsilon_{j,t} \,.$$

The model contains only definitions for year t, because the physical intensity ratios $\varepsilon_{j,t}^f$ are assumed known. To obtain estimates of demand for the different fuels in the next year, we need information on $GVAr_{j,t+1}$ and $\varepsilon_{j,t+1}^f$. We will formulate an update of $\varepsilon_{j,t}^f$ (based on microeconomic considerations) that change the descriptive model (1) through (5) into an economic model. However, first we need to identify for what purposes energy is used in production, and we must determine if this energy can be replaced by natural gas.

2.1 Energy Utilization in Production

Energy utilization in production can be classified into four types. (i) *Internal and external transport,* for which natural gas can be applied in the form of compressed natural gas (CNG). CNG is feasible only in case of a high annual mileage, and can be neglected here. Note that in our case study some CNG is used in Jakarta in busses and taxis, but these activities belong to the transport sector. (ii) Natural gas as *feedstock* for production. Feedstock applications are very specific applications; on Java there is only one iron and steel factory, and two fertilizer plants. (iii) *Captive power generation*; the conversion to natural gas of existing (diesel) combustion engines for power generation is technically feasible, but in our case it can be precluded in advance for economic reasons (high investment costs). For new investments in manufacturing we assume that the Java-Bali power grid is able to supply sufficient electricity, so no captive electricity generation is required. We do not, however, exclude other power applications, such as shaft power for compression. These latter applications are feasible only when there are favorable conditions for combined heat/power generation (cogeneration). (iv) *Production of heat* for production processes is the most interesting application for natural gas. The number of technologies for fuel application in production is limited [7], [16]. Two main principles for heat production can be distinguished: *central heat production* and *in-situ heat production*. These two types will be discussed next.

Central heat production is applied whenever solid or liquid fuels are used, unless a temperature of more than 200 degrees centigrade is required (the maximum temperature of steam). In central heat production there are two main steps. First, a fuel is combusted in a boiler or generator to produce a secondary form of energy (say) steam. Then this steam is transported to, and used in, the production process through a steam based technology; for instance, steam injection or mantle heating. In the same way we can start with the production of a hot liquid, mainly hot water. In some cases the secondary heat carrier is not used directly in the production process, but is fed into an intermediate heater to heat a tertiary energy carrier, which is then used in the production process.

In-situ heat production means that the fuel is combusted either very close to the place where the heat is needed (and the hot gas or liquid is used in the production process in the same way as in case of a boiler or generator) or the fuel is used directly in the production process [7], [16]. The main advantage of in-situ heat production is smaller heat losses. A reduction of these losses from 30 to 70% of the gross heating value in case of central heat production, to losses of 5 to 30% in case of in-situ heat production can be achieved. Another advantage is that natural gas is a clean fuel, so there is no contamination of the production process.

So the main opportunity for natural gas in manufacturing is in heat production, for which there are four main primary fuels: industrial diesel oil (denoted in our model by d), fuel oil (symbol o), coal (or c), and natural gas (or g). In central heat production these four fuels are substitutes with respect to net heat production, although coal is not considered an alternative in most production processes. For later use we define two sets: the set of primary fuels for new investments $F = \{d,o,c,g\}$, and the set of fuels for conversion $F_c = \{d,o,c\}$.

Note that central heat production is a putty-(semi-)putty technology, because a boiler or generator can easily be converted to another fuel, whereas in-situ heating is an example of putty-clay technology, because conversion to another fuel is not possible without considerable costs, and the adjustment needed resembles a new investment [4].

2.2 Value of Natural Gas in Heat Applications

For heat applications a company will switch from the current fuel to natural gas only if the price that the company is willing to pay for natural gas is higher than the actual price. The analytical measure for a consumer's willingness to pay is the *netback value*, defined as the maximum price a rational consumer is willing to pay given all other costs; that is, the price at which the net present value (NPV) of the investment in conversion becomes zero. The netback value for conversion from fuel f to fuel g for production process j in year t is denoted by $NBc_{j,t}^{f,g}$.

Whenever the actual price of natural gas is below the netback value, it is profitable for the company to convert the production process from the current fuel to natural gas. However, to evaluate small investments (such as conversion) companies use a maximum payback period as criterium. In practice a maximum payback period of three years is often used, and so do we.

Based on the netback value, we can define an indicator function $\delta_{j,t}^{f,g}$, which has the value one if it is profitable for the company to convert the production process using fuel f to natural gas (g), and which is zero otherwise:

$$\delta_{j,t}^{f,g} = \begin{cases} 1 & \text{if } P_{j,t}^{g} \leq NBc_{j,t}^{f,g}, \; f \in F_c; \\ 0 & \text{elswhere}. \end{cases} \tag{6}$$

In the same way as we did for natural gas, we can define the netback value and indicator function for the other fuels.

Note that if the choice of fuel was optimal in the past, there is no reason to assume that there will be a fuel other than natural gas to replace the current fuel, unless there is a major change in the country's energy pricing policy.

For *new* investments we can apply two netback concepts: one based on cost advantages, and one based on the market price of the product produced [3, pp 67-70 and pp 84-86]. In most production processes the heat application system is only loosely coupled with the actual production process [7], and energy is only a minor input factor; in these cases minimizing costs suffices [6].

In case the production process chosen either depends strongly on the fuel (a case in point is direct reduction steel production and other feedstock applications), or the fuel costs are substantial (more than 7% of total input costs), the netback value based on the market price of the final product must be used. Based on the netback value for new investments ($NBn_{j,t}^{f,g}$), we can define an indicator function $\delta_{j,t}^{f}$, similar to (6) for every fuel $f \in F$. Note that there is only one fuel for which this indicator is 1 for all other fuels.

2.3 Forecasting the Demand for Natural Gas

The value of natural gas (and other primary fuels) in production as indicated by the indicator functions can be used to "estimate" the demand for natural gas by a manufacturing subsector. We assume that for year t_0 data are available that are detailed enough to represent every subsector by one production process. With these data we can estimate the physical intensity ratio of subsector j for conversion of the existing production to natural gas, when gas becomes available and its price becomes known.

Let $D_{j,t}^{f}$ with $f \in F_c$ denote the amount of fuel f used in subsector j to produce the current amount of heat. In general there will be efficiency differences among fuels producing the same amount of heat. So to replace $D_{j,t}^{f}$ by natural gas, we have to take into account this difference in efficiency, denoted by $\tau_{c,j}^{f,g}$. The physical intensity ratio for natural gas in subsector j in year $t > t_0$ based on conversion to natural gas $\varepsilon_{j,t}^{g,c}$, can be estimated by

(7) $$\varepsilon_{j,t}^{g,c} = \frac{\sum_{k=t_0}^{t} D_{j,k}^{g,c}}{GVAr_{j,t_0}} = \frac{\sum_{k=t_0}^{t} \sum_{f \in F_c} \delta_{j,k}^{f,g} \tau_{c,j}^{f,g} E^{f}(D_{j,t_0}^{f})}{GVAr_{j,t_0}}.$$

The demand for natural gas in year t based on conversion is

(8) $$D_{j,t}^{g,c} = \sum_{f \in F_c} \varepsilon_{j,t}^{g,c} GVAr_{j,t_0}.$$

The remaining demands for the fuels $f \in F_c$ in year t based on investments before the year $t_0 + 1$ are

(9) $$D_{j,t}^{f,c} = \varepsilon_{j,t}^{f,c} GVAr_{j,t_0}$$

with $\varepsilon_{j,t}^{f,c}$ defined as

(10) $$\varepsilon_{j,t}^{f,c} = (1-\delta_{j,t}^{f,g})\varepsilon_{j,t-1}^{f,c} \ .$$

$\varepsilon_{j,t_0}^{f,c}$ is based on (7) with $t = t_0$, and $\delta_{j,k}^{f,g}\tau_{c,j}^{f,g}$ replaced by $(1-\delta_{j,k}^{f,g})$. Once $\varepsilon_{j,t}^{f,c}$ becomes zero, it will remain zero, so equipment converted to natural gas will remain on gas. The model can be easily adjusted to cover switches from natural gas back to other fuels also. However, in case of a consistent energy pricing policy, such a switch is not very likely.

The set of equations (7) through (10) does not suffice to estimate the demand for natural gas, since new investments are not included. Let $\tau_{n,j}^{f,g}$ denote the efficiency of production based on natural gas technology compared with production based on the technology for fuel f. The physical intensity ratio for natural gas in subsector j based on new investments can be estimated by:

(11) $$\varepsilon_{j,t}^{g,n} = \frac{D_{j,t}^{g,n}}{GVAr_{j,t_0}} = \frac{\delta_{j,t}^{g}\tau_{n,j}^{f,g} E^{f}(D_{j,t_0}^{f})}{GVAr_{j,t_0}}.$$

In (11) we can substitute any other fuel $f_1 \in F \backslash f$ for g to estimate its physical intensity ratio.

Now we can estimate the total demand for every fuel f for year t, with $t > t_0$. To avoid problems in the initial stage when gas is introduced, we assume that the production capacity of subsector j is fully utilized in year t_0, and that $\Delta GVAr_{j,t} \geq 0$ for $t \geq t_0$. These assumptions are reasonable for the booming economy of Java. The demand for natural gas due to new investments is

(12) $$D_{j,t}^{g,n} = \sum_{k=t_0}^{t} \varepsilon_{j,t}^{g,n} \Delta GVAr_{j,k}.$$

The total demand for in year t is

(13) $$D_{j,t}^{g} = D_{j,t}^{g,c} + D_{j,t}^{g,n} .$$

Note that the superscript g in (11) through (13) can be replaced by every $f_1 \in F \backslash f$.

Till now we assumed that there is no energy saving technical progress that would lead to a decrease in demand for energy in the future. Rogner [13] expects an average saving of 0.5% per year in industrial applications. This trend can be easily introduced in equations (7) and (11).

3 DATA REQUIREMENTS AND DATA CONSTRUCTION: JAVA CASE

To apply (7) through (13) we need the netback values and an appropriate division of the manufacturing sector. The data required for the application of the NPV criterion are: (i) the investment costs in energy equipment; (ii) the operating and maintenance costs for new and converted energy systems; and (iii) the amounts of fuel used for the different applications and their prices.

3.1 Available data

Starting point for our analysis of industrial energy utilization is the 1987 industrial survey conducted by the Indonesian Bureau of Statistics (BPS). BPS surveyed all establishments on Java that have more than twenty employees. This survey contains (among others) data at the

International Standard Industrial Classification (ISIC) five digit level [15], on the exact location of the establishments surveyed, their total energy consumption, quantities of the different fuels consumed; financial data on fuel costs, labor costs, and other input costs, and on value added.

For our purpose the energy data contained in the BPS survey have one major drawback: they are not divided according to the main forms of energy application in production, mentioned in Section 2. To obtain information on the data for netback calculation and on the relative importance of the different forms of application in the total production, Gasunie Engineering conducted a survey, which is discussed next.

3.2 The Gasunie Engineering survey

To reach maximum coverage of both energy consumption, and energy technologies used in the production processes, we applied the following procedure to select a sample from all 10,167 establishments in the BPS survey. From the set of all establishments we first removed all establishments in ISIC five digit subsectors for which we know that the application of natural gas in the production process is absent or can be neglected; manufacturing of batiks (code 32114), production of jewelry (code 39010), etc.

If we randomly selected a sample from the remaining set of establishments, we would most likely end up with a selection of small businesses. For our purposes it is more interesting to study the larger energy users, because there is a better chance that they represent Java's state of the art in energy application and that they have a more reliable information system for our survey. Therefore we removed all establishments with an energy use of less than 80,000 m^3 gas equivalents (mge) (after deducting the consumption of electricity purchased, automotive diesel and gasoline, and natural gas used[1]). This reduces the set of establishments to 1,527.

Java's manufacturing sector is concentrated in a few geographical areas, which are also candidates for investing in gas transmission and distribution. Therefore, the establish-

[1] In West Java a small gas distribution system already exists. It supplys gas to some small industries, and residential and commercial consumers. Gas from LPG production that would otherwise be flared, is mainly used by one iron and steel factory (using a direct reduction production process) and a fertilizer factory [8].

ments visited should be in West Java either in the industrialized area called JaBoTaBek (Jakarta-Bogor-Tangerang-Bekasi), or in the Bandung area; in East Java in the Surabaya-Gresik area; and in Central Java in the Semarang area. In those three areas altogether 90 to 95% of the total current industrial activity is concentrated.

A total of 318 establishments were visited by a multi-disciplinary team of energy experts. A total of 241 surveys could be completed successfully. Because of their large energy use, eight bulkconsumers were studied separately, namely two nitrogen fertilizer plants, five cement factories, and one iron and steel factory. So in total 248 establishments were surveyed.

Indonesia has plans to invest in the production of basic chemicals. Currently this subsector is still very small. The demand assessment for this subsector was based on these plans, and will not be discussed here. However, the plans are based on naphtha as feedstock. Natural gas will be used only for heat production. In the production of chemicals the cleanliness of gas is a big advantage.

Of the completed survey forms, 115 were from the JaBoTaBek area, 29 from the Bandung area, 54 from the Surabaya-Gresik area, and 43 from the Semarang area. If a five digit subsector in an area was selected for the survey, we always chose the largest establishment still in the set. This was done for two reasons. First, we wanted the survey to cover at least 20% of the energy used by the subsector. Second, choosing the larger establishments increases the chance that the technology used will be a better representative for the current state of the art in Indonesia. In a competitive market, efficient energy use forces less efficient companies to improve their energy use too [14].

The survey also gathered information on the ground-plan of the energy utilities and the heating equipment in the establishments visited. The ground-plan is used to estimate (i) the investment cost for new plants based on different fuels, and (ii) the investment costs for conversion of an existing plant to natural gas. For the assessment of the investment costs we also gathered information on prices of equipment and the construction costs.

Data on the Operational and Maintenance costs (O&M) were obtained by including a set of figures based on previous experience. For utilities the O&M was set as a percentage of the total investment costs in utilities. The figures were checked against the actual figures of the establishments visited, and if necessary adjusted.

The survey was also used to obtain the amount of fuel needed in the production processes. The analysis of the energy system included an assessment of the technical state the equipment used. If energy utilization deviates significantly from what is expected in a similar production process outside Indonesia, the future demand will be gradually reduced with the opening of the domestic market for foreign competitors [17].

3.3 An example: metal products

BPS distinguishes twenty five ISIC five digit subsectors within the ISIC two digit subsector 38. The products produced range from wire for spectacles to steel pipe. However, the establishments in this subsector use energy either to galvanize their products or to coat the surface. So from an energy point of view, two subsectors instead of twenty five are sufficient to analyze this two digit sector at the production process level. For a more comprehensive discussion on production processes and statistical data see Brown, Hamel and Hedman [2], and Van Groenendaal and de Gram [16]. The sequel of this example is restricted to galvanization, denoted as production process 38A.

A flowchart of production process 38A based on central heat production is given in Figure 1a. Since the actual galvanization requires a temperature of more than 400 degrees centigrade, in-situ heating is required; see block L2. All other heat applications use steam from a central boiler. The technologies used are indicated in the left corner of Figure 1a. A flowchart for the same production process based on natural gas is given in Figure 1b; technologies are again indicated in the left-hand corner.

The costs for a galvanizing production unit are displayed in Table 1. The first column indicates the different energy consuming phases of Figure 1. The symbols B1, F1, etc. denote the technologies also displayed in Figure 1. For the fuel supply system and for the heat application equipment Table 1 contains investment costs, operating and maintenance costs, and the amount of fuel needed. The conversion to natural gas is based on converting a production process using fuel oil[2]. The data are for a plant of average size, but the actual

[2] Fuel oil is the fuel most used, and in case of energy prices based on economic efficiency it is the most likely competitor for natural gas.

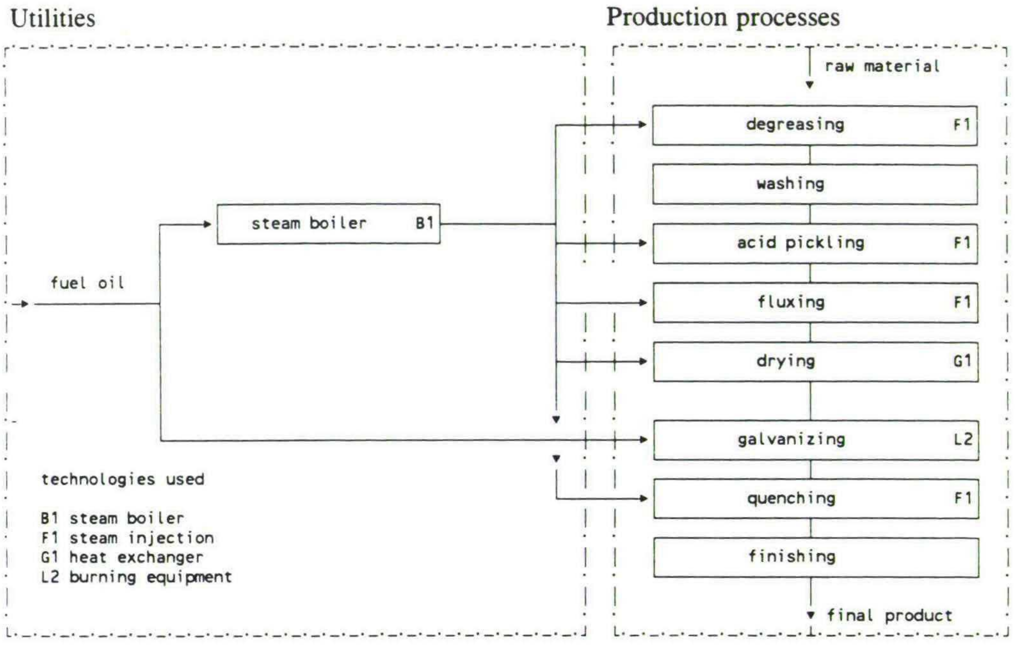


Figure 1a: Central heat production for galvanization of metal products

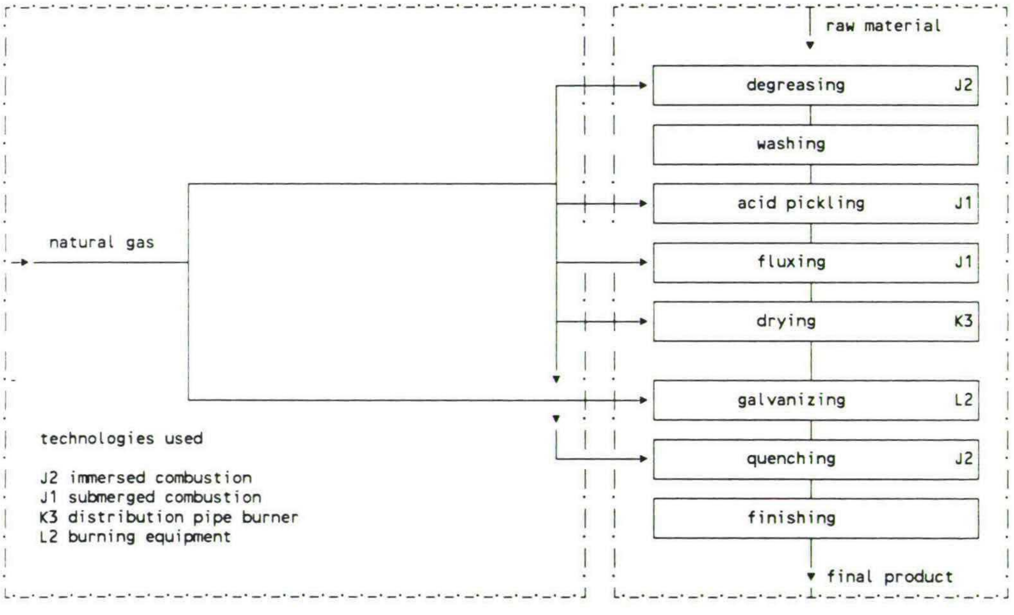


Figure 1b: In-situ heating for galvanization of metal products

Table 1: Investment, O&M, and energy use for production process 38A

	fuel oil				diesel oil			
equipment		inv.[1]	O&M[1]	fuel[2]		inv.[1]	O&M[1]	fuel[2]
fuel supply		37.4	1.3			29.8	1.0	
heat transport		36.1	1.8			36.1	1.8	
steam boiler	B1	261.6	11.2	473	B1	254.9	9.0	457
degreasing	F1	10.9	0.4		F1	10.9	0.4	
acid pickling	F1	21.8	0.8		F1	21.8	0.8	
fluxing	F1	21.8	0.8		F1	21.8	0.8	
drying	G1	23.4	0.8		G1	23.4	0.8	
galvanizing	L2	68.0	3.4	247	L2	68.0	2.4	239
quenching	F1	10.9	0.4		F1	10.9	0.4	
Total plant		492.2	20.8	720		477.8	17.6	696
Per 1000 kg [3]		41.014	1.736	0.060		39.819	1.470	0.058
equipment	natural gas				conversion to gas			
fuel supply		14.9	0.4			7.9	0.2	
heat transport						-	1.8	
steam boiler					B1	30.0	7.8	453
degreasing	J2	25.6	0.9	37	F1	-	0.4	
acid pickling	J1	53.6	1.8	65	F1	-	0.8	
fluxing	J1	53.6	1.8	65	F1	-	0.8	
drying	K3	39.7	1.4	33	G1	-	0.8	
galvanizing	L2	68.0	2.4	239	L2	-	2.4	191
quenching	J2	25.6	0.9	37	F1	65.0		
Total plant		281.0	15.4	475		102.9	15.4	644
Per 1000 kg [3]		23.4	0.8	0.040		8.6	1.3	0.054

[1] In million rupiah.
[2] Energy use in 1,000 mge per year.
[3] Investment and O&M in 1,000 rupiah.

size of a reasonably designed plant has no large influence on the netback calculations. The efficiencies of natural gas (symbol g) in process 38A relative to fuel oil (o) and diesel oil (d) are for new investments: $\tau^{o,g}_{38A} = 475/720 = 0.66$ and $\tau^{d,g}_{38A} = 475/696 = 0.68$.

Production process 38A can be used to evaluate the opportunities for natural gas in the ISIC five digit subsectors 38190, 38200, 38311, 38330, 38411, and 38430. Coal is not considered here because coal is feasible only in a limited number of production processes.

With respect to the different forms of energy used in total production, the survey shows that on average 8.3% is used for road transport, 0% for feedstock, 29.5% for electricity production, and 62.3% for central heat production in boilers or other central heating equipment; so 62.3% of the total energy used can be replaced by natural gas.

Table 2: Production processes and ISIC five digit subsectors

Process code and name	Corresponding ISIC/BPS codes	No. of establish-ments
31A Milk powder& sweetened milk	31121	16
31B Coconut oil from coconut	31151,31159	81
31C Bakery products	31179	225
31D Sugar manufacturing	31181	58
31E Tea processing	31220	148
31F MSG from molasses	31270	16
31G Beer from malt	31320,31330,31340	88
31H Tobacco products	31410,31420,31430,31490	784
31I Other products (mainly steam)	31112,31130,31140,31171,31190, 31241,31242,31250,31280, 35210,35233, 39090	1 140
31J Other products (mainly furnaces)	31260,31290	248
31K Other products (mainly electricity)	31111,31122,31161,31163,31164,31169, 31210,31230, 35120,35140,35222,35232,35290, 36900	730
32A Cloth from fiber	32111,32112,32113,32115, 32120,32130,32140,32160,32190, 32210,32290, 32310,32330, 32400	2 639
33A Manufacturing of plywood	33111,33112,33113,33114, 33190, 33210,33230	419
34A Paper from board	34111,34112	51
34B Containers from board	34120,34190,34200	442
35A NaOH & Cl_2 from NaCl	35110	11
35B Zinc Oxide from zinc ingot	35110	22
35C H_2SO_4 from sulphur	35110	11
35D Inorganic chemicals	35110	11
35E Industrial organic chemicals	35110	11
35F Fatty acids	35110	22
35G Fertilizer	35120	2
35H Resin, plastics and synthetic fibre	35130	7
35I Drugs and medicine	35221	155
35J Soap from palm oil	35231	46
35K Tires from rubber	35510,35521,35523,35590	239
35L PVC wares from PVC resin	35600	496
36A Clay products	36110	39
36B Pressed and blown glass	36210	28
36C Sheet flat glass	36220	4
36D Cement	36310	5
36E Concrete products	36320	311
36F Quick lime from limestone	36330	66
36G Bricks & tiles from clay	36410,36420	468
37A Iron and Steel from pig iron	37100 PT Krakatau Steel	1
37B Reinforcement bars from scrap	37100 (rest)	22
38A Galvanizing	38190,38200,38311,38330,38411,38430	447
38B Surface coating on metal	38111,38112,38113,38120,38130,38240, 38320,38340,38440,38450,38460,38490,38500	653
	Total	10 167

3.4 Constructing subsectors

In our demand model (Section 2) we defined a subsector as a set of establishments with the same production process from an energy point of view. Using this criterion, we divided the manufacturing sector into 38 different subsectors; see Table 2. Note that there is a remarkable difference in the number of ISIC five digit subsectors represented by one production process.

ISIC two digit subsector 31 (Food and Beverages) is subdivided into 11 sectors, according to the use of energy in the production process. (A complete description of all processes is given in [7]). All ISIC five digit subsectors that are covered by production process 31K use electricity only.

For subsector 34 it suffices to distinguish two production processes, namely paper (34A) and paper products (34B). Processes 34A and 34B are used in the ISIC three digit subsector 341, and process 34B is sufficient to describe ISIC subsector 342.

For subsector 37100 the five digit level is not detailed enough. The iron and steel factory (PT Krakatau Steel) using natural gas as feedstock for the direct reduction production process has to be analyzed separately (Kendrick, Meeraus and Alatorre, 1984). All other factories in subsector 37100 produce concrete bars from scrap using electric arc furnaces (process 37B).

Apart from subsector 37100, there is only one five digit subsector for which a direct link between data on the ISIC five digit level and a single production process is not possible; see Table 2, processes 35A through 35F. This sector comprises 88 small, often old establishments. Most processes apply energy in reactors or tanks, and for separation of products and byproducts. These technologies are no longer loosely coupled to the actual production process, but depend on the design of the production process (in contrast to most other subsectors).

Some production processes can be used in more than one two digit subsectors, namely production process 31I is used in the two digit subsectors 31, 35, and 39; see Table 3.

4 RESULTS

Before we can calculate the netback values of natural gas in the production processes, we need assumptions on fuel prices. Although Indonesia exports oil, it is expected to become a net importer in the next decade; so within the project period there will be a shortage of oil. Therefore we set the price of oil at its boarder value, and till the year 2000 inflate it with the World Bank estimates on oil price increases [18]. To obtain real prices, we deflate by the expected increase in the Manufacturing Unit Value Index. The prices of oil products are based on the crude oil price adjusted for refinery margins, transport and distribution costs [6], [19]. Java's gas reserves are insufficient to meet long term demand, so gas has to be imported from other islands, where uncommitted reserves are available, although not abundant. An alternative use for this gas is LNG export. So the price of gas has to be larger than its net value in LNG export. This is achieved by fuel oil parity pricing (154.4 Rupiah/m^3 in 1989). The fuel oil parity pricing also meets the goal of revenue raising for the Indonesian government.

We set the price of coal at its boarder value, since part of the coal used by the cement industry is currently imported from Australia. The low sulphur coal from Kalimantan can easily be exported, and the quality of Sumatra coal is described as insufficient by representatives of the cement industry. After the year 2000 we assume that all real fuel prices grow at an annual rate of 1.5%.

We are now able to calculate the netback values. For 1989 these values are given in columns (3) and (4) of Table 3. Column (5) contains the amount of energy used in 1989, and column (6) the percentage used for heat applications that can be replaced by natural gas. Column (7) is the part of total sector GVAr (in billions 1983 Rupiahs) produced with the production process in column 2.

The fuel efficiency of subsector j ($\tau_{j,t}^{f,g}$) for new investments is given in column (8) and for existing productions in column (9). $\tau_{j,t}^{f,g}$ is calculated as the weighted average of the efficiencies per fuel (see the example in § 3.3), using as weights the amounts of fuel oil and industrial diesel oil (both in mge) in the total amount of replaceable energy (fuel oil plus diesel).

We use process 38A to illustrate the calculations of for the last four columns. The amount of gas per million GVAr for a new plant is (89.8/518)*0.622*0.68*1000 = 73.3, and for an existing plant (89.8/518)*0.622*0.92*1000 = 99.2. This potential demand becomes effective demand if the price of gas is less than the netback value in Columns (3) and (4); see columns (12) and (13) respectively. The last column shows that existing production is hardly ever converted. However, analyzing column (4) shows that an initial

Table 3: Potential and effective demand per million GVAr in 1983 prices

ISIC sub-sector (1)	PROCESS Nr	Name (2)	NB-value Rup./mge new (3)	ex. (4)	energy used ml.mge (5)	repl. energy %of(3) (6)	GVAr in 10^9 (7)	gas/oil efficiency (8)	(9)	potential mge/GVAr new (10)	ex. (11)	effective mge/GVAr new (12)	ex. (13)
31	31A	Milk	173	138	18.9	58.3	42	0.99	1.00	260	262	260	0
	31B	Coconut oil	236	152	27.8	87.2	47	0.81	0.99	418	510	418	0
	31C	Bakery	232	75	15.2	75.2	18	0.96	0.96	610	610	610	0
	31D	Man. sugar	163	152	132.1	85.7	204	0.98	0.98	544	544	544	0
	31E	Tea	185	132	47.2	65.6	47	0.97	0.97	639	639	639	0
	31F	MSG	216	158	59.7	91.8	29	0.80	0.99	1512	1871	1512	1871
	31G	Beer	243	151	18.3	92.9	105	0.83	0.99	134	160	134	0
	31H	Tobacco	306	152	34.3	69.3	1358	0.72	0.96	13	17	13	0
	31I	Other prod.	234	152	61.5	83.4	126	0.82	0.97	250	295	250	0
	31J	Other prod.	183	146	8.7	56.8	15	0.95	0.95	313	313	313	0
	31K	Other prod.	-	-	109.4	0.7	73	-	-	-	-	-	-
		Total					2064			142	156	142	27
32	32A	Textiles	231	154	633.6	57.4	1056	0.76	0.99	262	341	262	0
33	33A	Plywood	227	150	38.3	10.8	123	0.76	0.94	26	32	26	0
341	34A	Paper	166	146	272.2	78.0	97	0.98	0.98	2145	2145	2145	0
	34B	Paper prod.	201	153	65.9	70.5	42	0.90	1.00	719	799	719	0
		Total					119			1714	1738	1714	0
342	34B	Paper prod.	201	153	17.5	70.5	131	0.89	0.99	84	93	84	0
35110	35A	NaOH & CL2	236	156	2.5	25.0							
	35B	Zinc oxide	173	82	4.7	54.4							
	35C	H2SO4	165	145	1.6	99.5							
	35D	Inorganics	199	135	8.1	93.2							
	35E	Organics	224	135	5.6	100.0							
	35F	Fatty acids	205	149	57.0	86.1							
		Total	205	149	79.5	84.3	108	0.92	0.97	572	603	572	0
35120	35G	Fertilizer	100	-	664.1	1)							
35130	35H	Plastics	318	151	1.3	88.2	4	0.62	0.98	161	254	161	0
352	35I	Drugs & med.	352	94	23.4	62.5	222	0.80	0.98	53	65	53	0
	35J	Soap	181	158	22.9	100.0	49	0.92	0.97	430	453	430	453
	31I	Other prod.	234	152	85.6	83.4	61	0.82	0.96	96	113	96	0
		Total					332			117	131	117	67
355	35K	Tires	176	150	89.0	45.6	115	0.97	0.97	342	342	342	0
356	35L	PVC wares	212	141	61.7	63.1	131	0.88	0.98	262	291	262	0
36 (excl. cement)	36A	Clay prod.	169	139	67.0	78.6	26	1.00	1.00	2026	2026	2026	0
	36B	Blown glass	198	120	106.5	80.4	36	0.91	0.91	2164	2164	2164	0
	36C	Sheet glass	158	146	51.7	100.0	21	1.00	1.00	2462	2462	2462	0
	36E	Concr. prod.	225	133	21.2	27.0	80	1.00	1.00	72	72	72	0
	36F	Quick lime	173	76	11.8	0.0	2	0.99	0.99	0	0	0	0
	36G	Bricks	172	133	29.7	84.5	14	1.00	1.00	1793	1793	1793	0
	36	Total (rest)					179			1191	1191	1191	0
36310		Cement	172	139	908.7	1)							
37	37A	Iron & steel	108	-	1077.3	1)							
	37B	Reinf. bars	163	145	61.9	83.6	42	0.99	0.99	1220	1220	1220	0
38	38A	Galvanizing	326	116	89.8	62.2	518	0.68	0.92	73	99	73	0
	38B	Surf. coat.	403	150	86.2	65.9	502	0.62	0.98	70	111	70	0
	38	Total					1020			72	105	72	0
39	31I	Other prod.	234	152	68.4	83.4	31	0.82	0.97	152	180	152	0

1) These sectors comprise only a few companies, and are evaluated at the company level.

lowering of the price for gas by five Rupiahs per cubic meter is incentive enough for eleven more sectors to switch to natural gas. This is an interesting result for the marketing department of Indonesia's gas distribution company. If we weight the subsectoral demand for gas with its share in the total two digit GVAr, we get the gas intensity per million GVAr at the two digit level; see the last row of every block.

We do not use the results for the production processes 35A through 35E. Because process 35F dominates ISIC five digit sector 35110 (see columns (5) and (7)), and the subsector is small, we assume that the combined result based on the last row of the block (35110 in column (1)), is sufficient to forecast demand.

For the processes 35G, 36D, and 37A we use estimates of future production based on investment plans and estimated future demand, instead of growth in GVAr. The reason is that these processes comprise 2, 5, and 1 factories respectively. For the cement industry, gas is feasible in new investments; however, after 1995 the netback value becomes less than the price of natural gas, and coal is the optimal fuel. Currently the Indonesian government forces the cement industry to use coal. Since there are no plans for new investments before 1995, we assume that cement will remain on coal, except for those production units that already use gas.

No new production facilities for fertilizer (process 35G) will be established on Java. The current price of gas, 60 Rupiah/m^3, is to low. Given the fact that natural gas is relatively scarce on Java, the netback value of gas in fertilizer production is too small to increase capacity.

The netback value of natural gas in iron and steel production (process 37A) is also below the market value of gas. The existing production units are under revision to boost capacity, but new gas based production units are not feasible from an economic point of view. If more steel is needed than can be produced, import of steel seems a more viable option.

4.1 Demand forecast

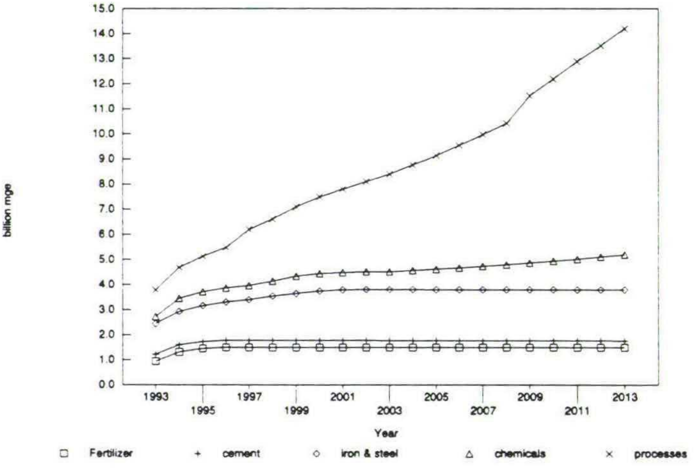
Before we can apply equations (7) through (13) to forecast the demand for natural gas, one other variable is needed: sectoral growth. The main assumptions for GVAr are given in Table 4; they are based on Indonesia's sectoral investment plans, and on private communica

Table 4: Summary of the assumptions for demand forecast

Period		1989-1993	1993-2000	2000-2013	
Average Growth	process				
GVAr		7.0%	5.8%	5.2%	
Manufacturing		10.6%	7.2%	5.9%	
Food & Beverages	(31A-31K)	8.3%	6.3%	5.5%	
Textiles	(32A)	13.0%	8.3%	6.1%	
Fertilizer	(35G)	8.0%	8.5%	0.0%	a)
Basic Chemicals	(35A-35F)	26.3%	8.4%	5.3%	b)
Cement	(36D)	5.8%	6.2%	5.3%	c)
Krakatau Steel	(37A)	9.6%	7.2%	5.9%	
Metal Products	(38A-38B)	13.5%	7.8%	6.4%	
All other processes		10.5%	6.8%	7.2%	

a No new investments in fertilizer production after the present plans have been realized.
b Also includes Indonesia's plans for investment in production of chemicals.
c The cement industry uses coal as fuel.

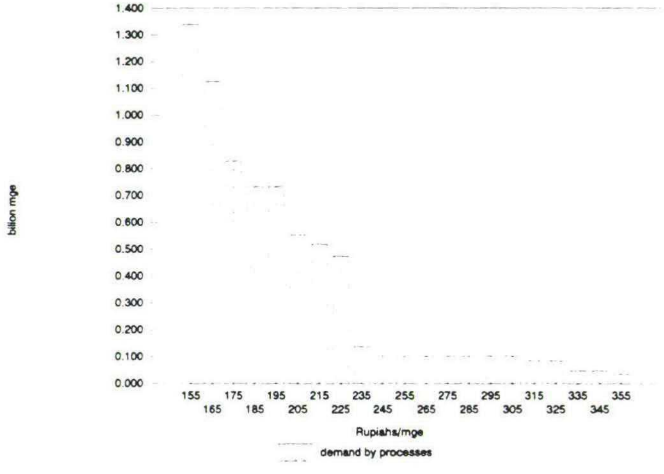
Figure 2: Demand for gas forecast



tion with the Indonesian bureau of planning. If we substitute the results of Tables 3 and 4 into our model, we can forecast effective demand for natural gas by the manufacturing sector; see Figure 2.

Note that not every establishment converts to natural gas, when gas becomes available. Experience with the introduction of natural gas in other countries shows that if fuel costs are less than 2% of the input costs, management is not interested in conversion; if the fuel costs exceed 7% of the input costs, they will always convert. For the subsectors for which the fuel costs as a percentage of total input costs are in the 2-7% range, say a%, we assume that a/5*100% of the subsector will convert. This approximation is in line with what gas application specialists experienced. Furthermore, sensitivity analysis shows that our long term demand forecasts are hardly affected by this assumption.

Figure 3: Demand-price sensitivity



Price sensitivity analysis is possible per year; see Figure 3. At a price of 155 Rupiahs/m^3 all new investments will use natural gas. A price increase of 10 Rupiahs/m^3 (keeping the price of oil products constant) induces a drop in demand. Processes 31D (sugar), 36E (concrete products), and 37B (iron from scrap) will use fuel oil. A second 10 cent increase affects the production of paper (process 34A), clay products (36A), and bricks (36F). With every price increase the number of processes using gas reduces; a large drop occurs when the price becomes larger than 225 Rupiahs, and gas is no longer feasible for process 32A (textiles). Above a price higher than 225 Rupiahs demand is small and is rather insensitive to relative price changes.

5 CONCLUSIONS

Our method of forecasting the demand for natural gas has clear advantages over other methods, such as demand analysis based on econometric modelling. Our method allows a detailed analysis of the effects of energy supply and energy pricing policies, taking into account differences in sectoral growth. For a manufacturing sector with a rapidly changing structure (such as Java's) our model can be easily adjusted in case new subsectors emerge.

Our method is parsimonious in the sense that it restricts the number of subsectors to the minimum number required, because the definition of subsector is based on the use of energy in the production process, and not on product produced. The definition allows comprehensive and reliable analysis of energy pricing policies, since changes in relative fuel prices show exactly which subsectors are affected. Therefore it is more than a model for demand forecasts: it is also an adequate tool for the design of pricing policy.

A drawback is that there is no link between sectoral economic growth and input costs. This link can, however, be included when the model is embedded in an overall economic model.

REFERENCES

Ang B.W., A statistical analysis of energy coefficients, *Energy Economics*, 1991, pp 93-110.

Brown H.L., B.B. Hamel and B.A. Hedman, *Energy analysis of 108 industrial processes*, Drexel University, Fairmont Press, Philadelphia, U.S.A., 1985.

DeAnne Julius and A. Mashayekhi, *The economics of natural gas: pricing, planning and policy*, Oxford University Press, 1990.

Fuss M.A., The structure of technology over time: a model for testing the the "putty-clay" hypothesis, *Econometrica*, 54(8), 1977, pp 1797-1821.

Fuss M.A., D. McFadden, and Y. Mundlak, A survey of funtional forms in the economic analysis of production. In M.A. Fuss and D. McFadden (eds.), *Production economics: a dual approach to theory and applications*, North Holland, 1978.

Gasunie Engineering, Study of an integrated gas transmission system on Java: Evaluation of options, Volume I, Gasunie Engineering BV & PT Ciprocon, Jakarta, October 1990a.

Gasunie Engineering, Study of an integrated gas transmission system on Java: Present industrial energy utilization, Volume II, Gasunie Engineering BV & PT Ciprocon, Jakarta, October 1990b.

Gelb A. and Associates, *Oil windfalls: blessing or curse?*, Oxford University Press, New York, 1988.

Howard R.B., L. Schipper, P.A. Duerr and S. Strom, Manufacturing energy use in eight OECD countries, *Energy Economics*, 1991, pp 135-142.

Jenne and Catell, Structural change and energy efficiency in industry, *Energy Economics*, 1983, pp 114-123.

Jing-Wen Li, R.M. Shrestha and W.K. Foell, Structural change and energy use, *Energy Economics*, 1990, pp 109-115.

Kendrick D.A., A. Meeraus and J. Alatorre, *The planning of investment programs in the steel industry*, John Hopkins University Press, Baltimore, Maryland, U.S.A., 1984.

Rogner H., Technology and the prospects for natural gas: Result of current gas studies, *Energy Policy*, 1988, pp 9-26.

Saunders R.J. and S. Gandhi, Energy efficiency and conservation in the third world, World Bank Policy Paper, World Bank, Washington D.C., U.S.A., 1993.

United Nations, *International standard industrial classification of all economic activities*, United Nations, Department of International Economic and Social Affairs, Statistical Office, 3rd rev., New York, 1990.

Van Groenendaal W.J.H. and F.H. de Gram, Generalizing net present value calculations for natural gas market determination, Tilburg University, 1994, in process.

Warr P.G., Comparative advantage and protection in Indonesia, *Bulletin of Indonesian Economic Studies*, 28(3), 1992, pp 41-70.

World Bank, Price prospects for major primary commodities, World Bank, Report No 814/88, 1988.

World Bank, Natural gas development planning study, Industry and Energy Operations Division, Country Department III, Report No. 10293-IND, 1992.

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