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BY

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Abstract

One sizable group of energy users in the Philippines is the collection of firms in the Special Economic Zones (SEZs). The production process among many of the firms in the SEZs includes heating, which currently uses the more expensive and less environment-friendly diesel or liquefied petroleum gas as fuel. Thus, natural gas is a potential cost-competitive and cleaner substitute for the feedstock currently used in both heating process and electricity requirements of firms in SEZs. Our objective in this study is to assess the likelihood of firms to switch to natural gas and determine the profile of power and fuel use among firms in manufacturing and agro-industrial SEZs. We find that the extent of knowledge about natural gas and their production technology process are the primary determinants of the likelihood to switch. Particularly, the knowledge that natural gas is a cost-competitive alternative along with the use of heating in the production process are critical to increasing a firm's probability of switching. Hence, energy-intensive manufacturing firms that use more expensive fuel sources such as diesel for heating are more likely to switch to natural gas. These results also help shed light on facilitating the efficient transition away from less environment-friendly fuels to relatively cleaner natural gas and renewable sources.

Keywords: Liquefied natural gas use, industry processes, Philippines, logit regression
JEL codes: L95, L6, N75, O13, O14, Q42, Q48, Q53

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1. Introduction

The Philippines has experienced a renewed economic dynamism, growing at an average of 6.3 percent from 2010-2019 (World Bank, 2020). Embodied in the Medium-Term Development Plan of 2017-2022 is the *Ambisyon Natin 2040*, a notional target to join the high-income countries by 2040 (Clarete et al., 2018). If the country is to realize this target, it should grow at a sustained high-level of 7% or more. This economic growth will be accompanied by increasing energy and electricity consumption (Danao and Ducanes, 2018). Energy demand is projected to reach 43,765 MW by 2040, almost four times the demand in 2018 (Department of Energy, 2019). The 100% electrification target across the Philippines by 2022 is also likely to contribute to additional demand (Asian Development Bank, 2018).

Since March 2020, the country and the rest of the world have been hit by the unprecedented COVID-19 pandemic. As operations of industrial facilities and commercial establishments slowed down, electricity generation and consumption have dropped (WESM-IEMOP, 2020). Economic growth forecast for the country (ADB, 2020; World Bank, 2020) turned sour. The lower economic growth trajectory means that electricity demand targets is reduced. The outlook for new investments in generation is especially bleak given the current excess capacity (Ravago and Roumasset, 2020). If and when the economy picks-up, the country may again face a problem of attracting sufficient investment in generation. While addressing the public health problem is and should be the primary concern, the country should not lose sight of the issue of attracting sufficient investment generation for the long-term economic recovery.

Addressing the recovery of energy demand becomes more challenging as production levels from Malampaya gas field, the country's indigenous natural gas field, are expected to decline starting 2022. Without a replacement energy source, a looming energy crisis is foreseen as the Philippines stand to lose over 3,400 MW from existing gas plants, responsible for about 29% of Luzon's power generation (DOE, 2020a). Importing liquefied natural gas (LNG) is seen as the immediate solution to prepare for the eventual depletion of Malampaya. As such, an LNG industry is emerging, and its development should be accompanied by appropriate regulation and some form of industrial policy. Presently, natural gas is being used for power and industrial sectors. These current uses may be expanded while other uses of natural gas can also be explored and taken advantage of as the LNG industry expands.

The COVID-19 pandemic and the anticipated depletion of Malampaya gas field present an opportunity to facilitate efficient transition to cleaner energy (Ravago and Roumasset, 2020). New investments in coal plants may be replaced by investments in LNG-fueled plants. This strategy together with falling costs of wind and solar power and taxes on coal generation that reflect the marginal damage costs of pollution create a promising condition for an energy transition that is a win-win for affordability and sustainability.

One sizable group of energy users is the collection of firms in the Special Economic Zones (SEZs). Due to its specialized facilities and technology, energy demand and intensity of firms in SEZs are recognizably greater than firms in non-SEZs. Despite this, most SEZs rely on grid electricity. In a JICA study (2011), grid electricity accounted for almost 83% of total fuel used among 82 establishments surveyed along the Batangas-Manila (BatMan 1) gas pipeline. Majority of the establishments preferred sourcing their power from Meralco (largest distribution utility in the country) because it is reliable, and it provides special discounted rates to big users of electricity. The production process in many of the firms in the SEZs includes heating, which currently uses the more expensive and less environment-friendly diesel or liquefied petroleum gas (LPG) as fuel. Thus, LNG is a potential cost-competitive and cleaner substitute for energy sources used in both heating process and electricity requirements of firms in SEZs.

With the foregoing, our objective is to determine the likelihood of firms to switch to natural gas and determine the profile of power and fuel use among firms in manufacturing and agro-industrial SEZs. We conducted a primary survey among SEZ firms in Laguna, Batangas, Cavite, Cebu, Pampanga, Benguet, Bulacan, and Metro Manila. The choice of SEZs as sample for this study is dictated by the engagement of firms in the manufacturing business. Given the importance of manufacturing in the structural transformation of an economy (see Daway-Ducanes and Fabella, 2015; de Dios and Williamson, 2015; and Ravago et al., 2019), it is vital to determine systems that will improve their productivity and efficiency.

The results of the survey provided insights that are useful as the country's LNG industry progresses. We find that the firms' extent of knowledge about natural gas and their production technology process are the primary determinants of the likelihood to switch. Particularly, the knowledge that natural gas is a cost-competitive alternative along with the use of heating in the production process are critical in increasing a firm's probability of switching. Hence, energy-intensive manufacturing firms that use more expensive fuel sources such as diesel are more likely to switch to natural gas. The results of the study also help shed light in facilitating the transition away from dirtier fuels to cleaner natural gas and eventually to renewable sources.

While our study covers only manufacturing and agro-industrial firms in ecozones, the results provides an indication of the extent of potential market for LNG in the country. To the best of our knowledge, our study is the first to use a primary survey data on manufacturing and agro-industrial firms with detailed information on electricity and fuel use in a developing country. Moreover, we contribute to the literature and help fill the research gap on studies investigating determinants of fuel switching among manufacturing firms in the context of a developing country.

We review related studies in the next section. Section 3 gives an overview on the use of natural gas in the Philippines. Section 4 presents our data and methodology. This section provides a description of our primary survey and selected results from the survey. We employ logistic and OLS regressions to examine the determinants of fuel switching. Section 5 discusses the results of our econometric analysis and the role of natural gas as bridge fuel towards an efficient energy transition. The last section offers recommendations and concluding remarks.

2. Related Literature on Fuel Switching to Natural Gas

There are a number of studies on interfuel substitution discussing the factors that influence likelihood of switching to another lower carbon energy source. Serletis et al. (2009) showed that high-income countries have larger interfuel substitution potential compared to middle- and low-income economies. Across sectors, higher potential of substitution between energy inputs were exhibited among industrial and transportation sectors versus residential and electricity generation sectors. There is likewise a need for a higher change in relative prices to encourage switching toward a lower carbon alternative.

Examining the interfuel substitution in the U.S., Serletis et al. (2010a) found that there is a limited ability to substitute one energy source for another. Their results suggest that fossil fuels will continue to be a major source of energy in the future. This finding may be unique to the US and not corroborated by other studies. For example, in another study by Serletis et al. (2010b), findings suggest that countries with higher level of technology tend to have less difficulty switching between energy inputs even in the short-run. In terms of interfuel substitution in the industrial sector, their findings revealed significant strong substitutability between natural gas and coal and mild substitutability between oil and natural gas, irrespective of whether the price of either fuels change.

Closely investigating the U.S. manufacturing sector, Doms (1993) examined interfuel substitution and the heterogeneity of energy technologies by using plant level data from the 1985 Manufacturing Energy Consumption Survey and Longitudinal Research Database. He found that both plant level characteristics (i.e. energy consumption, energy intensity, preference of an industry towards an energy technology) and energy market conditions (i.e. energy prices, availability, variance) greatly influence adoption of certain energy technologies. Results show that plants with significant energy consumption are more likely to adopt fuel switching technologies, indicating that fuel intensity is a factor for the fuel switching technology. Moreover, plants that involve energy intensive applications are more likely to rely on natural gas and distillate fuel oil. It was observed that as the price of natural gas increases, the predicted probability of relying solely on natural gas decreases. The severity of natural gas shortages of the 1970's likewise positively influenced the predicted probability of possessing fuel switching technology in 1985.

Using a fuel consumption at a 4-digit Standard Industrial Classification data in the UK, Steinbuks (2010) found that an increase in energy prices had limited effect on fuel's choice in the direct manufacturing process, contradicting Doms (1993). However, consistent with Doms (1993), Steinbuks (2010) showed that substitution takes place when there is a change in fuel demand specifically for distinctive energy-using processes such as machine drive, electrochemical process, and conventional electricity generation. The major reason for interfuel substitution in UK manufacturing is based on energy efficiency improvements in fuel-using capital stock across different technologies and production processes.

In China, the increasing demand for ethylene glycol gave rise to many natural gas-to-ethylene glycol plants. Yang et al. (2020) compared both natural gas-to-ethylene glycol and coal-to-ethylene glycol to the conventional oil-to-ethylene glycol process. They show that the coal-based plants have a significant cost advantage but manifested high energy consumption, low energy efficiency, significant CO_2 emissions and wastewater discharge. On the other hand, the technical and environmental performance of the natural gas-based plants is better than that of its of coal-based counterparts, but are disadvantaged in terms of total production cost and internal rate of return. Between natural gas-based plants and coal-based process, the former had a lower estimated capital investment making it a viable alternative for ethylene glycol plants using conventional oil.

Our contribution helps fill the research gap in the literature on the determinants of fuel switching among manufacturing firms in the context of a developing country. In scanning the literature, we find a paucity of studies investigating the determinants of fuel switching or substitution among manufacturing firms in developing countries. We find an example in Moss and Tybout (1994), which analyzes plant-level panel data from Chile and Colombia to assess how manufacturers might respond to carbon taxes and other policies that induce substitution between clean and less environment-friendly fossil fuels. However, it does not put emphasis on natural gas. Other studies on fuel switching in developing countries focus more at the household level (Giri and Goswami, 2018; Masera and Navia, 1997).

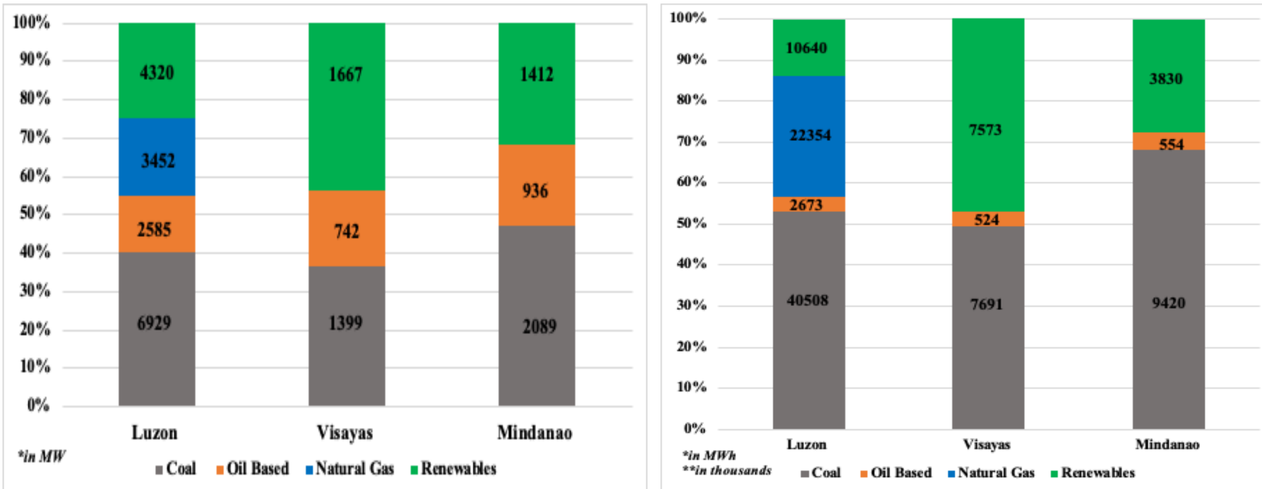
Our study likewise contributes to research on the feasibility of natural gas as a "bridge fuel" to facilitate efficient transition to cleaner energy and lower carbon growth in developing countries, averting costly subsidies to renewables (Roumasset et al., 2018). Drastic re-orientation of economic development towards low-carbon in developing countries may not be practical and realistic (Jakob et al., 2014). Natural gas has been referred to as "bridge fuel" since 1988 (Delborne et al., 2020) to mean as an alternative to other energy sources deemed unfavorable or unsustainable. Natural gas emits less carbon than coal given same amount of energy produced. Although, it is still not settled as to whether methane leaks are considered as emissions that offset the fewer carbon emission advantage of natural gas. Before natural gas could be a "bridge fuel," it has to be in itself stable and secure. Khayat Basiri et al. (2020) identified three factors, availability, infrastructure, and governance in measuring natural gas supply security at the distribution company level albeit only applicable to Tehran. A more secure natural gas supply reduces the disruptions influenced by internal factors (e.g. equipment failure), networks (e.g. sudden changes in demand, supply shortage), and environmental forces.

3. Natural Gas Use in the Philippines

The Malampaya offshore gas field has been the Philippines' sole source of natural gas since 2001. Discovered in 1990, Malampaya allowed the country to use natural gas as fuel for the power generation and industrial sectors and to produce electricity power for almost two decades. Power generation took the lion's share in gas usage with 98% and the remaining 2% was used for the industrial sector (DOE, 2018).

Currently, the country has three operating baseload combined-cycle gas turbine (CCGT) power plants all located in Batangas City. These are the 1000-MW Sta. Rita and 500-MW San Lorenzo Power Stations owned and operated by First Gen Corporation and the 1200-MW Ilijan Power Station operated by KEPCO. Newer gas plants also use gas from Malampaya including the San Gabriel mid-merit and Avion peaking plant (ADB, 2018). Figure 1 shows the installed generating capacity (MW) and gross power generation (MWh) by the three islands grid. In 2019, natural gas contributed 29% of the Luzon generation mix alongside other energy sources such as coal, oil, and renewable energy sources wind, solar, and biomass hydro, geothermal (DOE, 2020a).

Figure 1. Installed Capacity and Gross Power Generation, 2019.



a. Installed capacity b. Gross power generation

Source of basic data: (DOE, 2020a)

The use of natural gas was also explored for the transport sector from 2008 to 2014 with the DOE's Natural Gas Vehicle Program for Public Transport. A total of 41 compressed natural gas (CNG) buses plied the Batangas - Laguna - Metro Manila routes. The pilot run displaced a total of 4 million liters of diesel fuel, equivalent to US$ 2 million forex savings and a corresponding reduction in carbon dioxide (CO_2) emission of around 4,400 metric tons (DOE, n.d.).

Without any replacement, the anticipated depletion of the Malampaya offshore gas field by 2022, pose a danger of potential energy crisis. As such, the country is preparing to fill the gap by importing LNG. Among the private sector, there is a race to construct an LNG terminal. The first one to operate has the potential to capture the benefits of a first-mover advantage by nature of the industry. As of June 2020, at least eight natural gas projects are in the pipeline (DOE, 2020b) Moreover, the LNG industry is responding to fill the gap due to the depletion of Malampaya gas field. As the LNG industry emerges, it is critical to understand its potential market to aid in crafting appropriate regulation that can nurture the industry development.

4. Data and Methodology

4.1. Description of the survey

We conducted an online survey in August-September 2019 among SEZ firms classified as manufacturing and agro-industrial in the provinces of Laguna, Batangas, Cavite, Cebu, Pampanga, Benguet, Bulacan, and Metro Manila. For complete details of the survey, see Ravago et al. (2020). Our survey aims to characterize the profile of the firms in the Philippine Economic Zone Authority (PEZA) that are more likely to adopt alternative fuels and primary energies such as natural gas, solar, and wind in their existing production processes.

In 2019, there are a total of 396 operating SEZs nationwide ranging from manufacturing economic zones, information technology parks/centers, agro-industrial economic zones, tourism economics zones, and medical tourism parks and centers in the country. Adhering to the standard ethics protocol in conducting research and keeping the survey optional, we employed a non-probability sampling procedure targeted to manufacturing and agro-industrial SEZs. On the viability of LNG as a fuel used in the production process, the results from the FGDs highlighted that LNG is more feasible among firms that operate boilers. Boilers are used to apply heat in the production of manufactured goods. Power-intensive manufacturing companies are those that use boilers, for instance, food manufacturers and agro-industrial companies.

Our survey was sent to 61 manufacturing and agro-industrial SEZs with a total of 1,613 operating firms (Freedom of Information, 2018). We obtain a total of 115 firm-respondents, 100 from the online survey and 15 from the pilot survey. These firms are from 24 SEZs out of the 61 SEZ we targeted. Published research on organization and workplace typically has 15-60 participants (Saunders and Townsend, 2016). Our sample of 115 firms is considered a successful return given that the survey is voluntary. Our sample is larger than the 82 firms surveyed by JICA (2011), although the JICA study covers only firms in economic zones along the proposed Batangas-Manila (BatMan 1) natural gas pipeline (i.e., Batangas and Laguna areas only). Table 1 presents the profile of our respondents. Out of the 115 respondents, a considerable number are from SEZs located in Laguna at 64%, followed by respondents in Batangas at 10%. The rest are from Cavite, Cebu, Pampanga, Benguet, Bulacan, and Metro Manila. Note that these provinces are all in the Luzon and Visayas islands.

Our survey instrument collected information on the general profile of the firms, production and operation, utility consumption, fuels used in production, and aptitude on alternative fuels. The questionnaire was created using the subscription-based survey platform SurveyMonkey (see https://www.surveymonkey.com). The data and questionnaire are accessible in Ravago et al. (2020). Respondents representing the firms are directors, supervisors, managers, or officers for finance and accounting; sales and marketing; human resource; pollution control and environment; production and operations; or facilities, equipment, and utilities.

Table 1. Profile of firms by ecozone

Ecozone by province	No. of respondents %	N	Firm size %	Mean	Annual production sales (in million PhP) %	Mean	Annual per-capita production sales (in PhP) %	Mean
Laguna	**64.35**							
Laguna Technopark SEZ	19.13	22	4.98	548	7.68	6,473	23.08	65,021,600
Carmelray Ind. Park II	13.91	16	5.07	558	3.23	2,725	1.06	2,972,165
Calamba Prem. Int'l Park	13.04	15	2.42	266	0.25	206.7	1.43	4,025,332
Filinvest Tech. Park Cal.	4.35	5	0.21	23	0.12	100	2.74%	7,710,262
Laguna Int'l Industrial Park	4.35	5	2.54	280	4.82	4,060	2.89	8,135,588
Light Ind. & Science Park I	3.48	4	6.77	745	11.92	10,050	3.21	9,036,807
Greenfield Automotive Park	2.61	3	0.32	35	4.03	3,400	22.19	62,515,124
Laguna Technopark Annex	1.74	2	3.00	330	0.71	600	1.10	3,095,632
Light Ind. & Science Park II	0.87	1	0.63	69	0.12	100	0.51	1,449,275
Toyota Sta. Rosa SEZ	0.87	1	3.04	334	11.86	10,000	10.63	29,940,120
Batangas	**10.44**							
Lima Technology Center	6.09	7	6.93	762	10.29	8,671	2.71	7,633,361
First Phil. Industry Park	3.48	4	9.96	1,096	26.79	22,580	10.22	28,782,899
Keppel Phils. Marine SEZ	0.87	1	6.98	768	0.83	700	0.32	911,458
Cavite	**8.70**							
Golden Mile Business Park	6.09	7	3.67	404	0.12	100	0.98	2,761,036
People's Tech. Complex	1.74	2	1.12	124	0.59	500	1.44	4,061,762
Golden Gate Bus. Park-CEPZ	0.87	1	0.22	24	0.12	100	1.48	4,166,667
Cebu	**7.83**							
Mactan Economic Zone	3.48	4	14.87	1,637	3.11	2,625	3.09	8,701,762
West Cebu Industrial Park	2.61	3	0.50	55	0.44	366.7	2.85	8,015,873
Cebu Light Industrial Park	1.74	2	17.26	1,899	11.86	10,000	3.17	8,936,515
Pampanga	**6.09**							
Pampanga Economic Zone	4.35	5	1.47	162	0.17	140	0.76	2,140,653
TECO Industrial Park	1.74	2	3.70	408	0.36	300	1.29	3,645,833
Benguet	**0.87**							
Baguio City Economic Zone	0.87	1	3.17	349	0.12	100	0.10	286,533
Bulacan	**0.87**							
Victoria Wave SEZ	0.87	1	0.99	109	0.36	300	0.98	2,752,294
Metro Manila	**0.87**							
MacroAsia Ecozone	0.87	1	0.18	20	0.12	100	1.77	5,000,000
Total	100.00	115	100.00	494	100.00	3,987	100.00	18,980,590

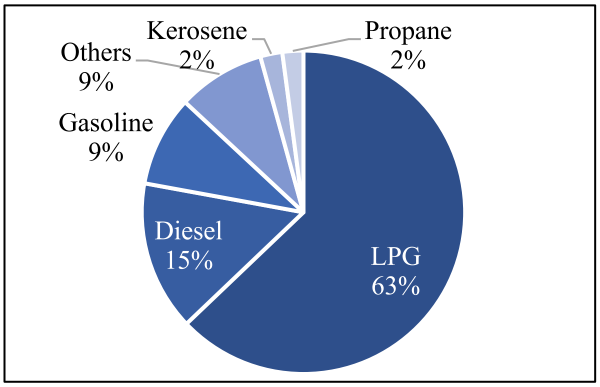
Note: 1 USD = 49 PhP as of August 2020.

4.2. Results of the survey

We present selected results of the survey focusing on respondents' aptitude and perception on natural gas. Out of the 115 respondents, only 56 firms use any fuel other than electricity in their processes. The average fuel expenditure of 56 firms in our sample gives an indicator on the usage quantity of each type of fuel. From the average total monthly expenditure of PhP 852 thousand, 63 percent is spent on LPG for fuel in both heating and non-heating production processes.

Our survey also asked for the common production processes of firms, whether they have heating or no heating component. For those with heating component, electricity is the main power source of their equipment. For example, a total of 45 firms with heating component has fabrication as one of its production processes. Of the 45 firms, 40 of them rely on electricity, 3 on LPG, and 1 firm used diesel and kerosene, respectively. In Ravago et al. (2020), Appendix 5 Table IV-4 shows the information on the number of firms and their production processes by fuel use.

Figure 2. Expenditure share per fuel



Fuel	Mean expenditure (PhP)	Share (%)
LPG	535,714.60	63
Diesel	127,768.20	15
Gasoline	77,142.98	9
Others	74,754.30	9
Kerosene	18,750.04	2
Propane	17,857.16	2
Total	851,987.30	100

Notes: In the survey, LPG is defined as a combination of propane and butane. Biodiesel, bunker, and coal were not included in the figure. Other fuels include electricity, hydrogen, biomass, Thuban, nitrogen, oxygen, argon, helium, rice hull, hydraulic oil, engine oil.

Table 2 presents the firms' state of knowledge on natural gas. Less than half of the respondents (44%) have limited knowledge on natural gas. This is expected since natural gas is currently not widely commercially available in the Philippines.

Table 2. Firms' extent of knowledge on natural gas

	Natural gas
1 (Limited)	44.35%
2	14.78%
3	29.57%
4	9.57%
5 (Advanced)	1.74%
Weighted Mean	2.10
N	115

Note: Responses vary from 1 (limited knowledge) to 5 (advanced knowledge).

The survey also asked the respondents regarding their perception on and openness to switching to natural gas. Despite respondents citing limited knowledge on natural gas, a greater number of them perceived natural gas to be safe and cost-competitive (Table 3). They are also open to switching to natural gas, with 63 percent responding positively to openness towards switching.

Table 3. Perception on and openness to natural gas, by number and percentage of firms

	Safety		Cost-competitiveness		Openness to switching	
	%	N	%	N	%	N
Yes	57.39	66	65.22	75	63.48	73
No	42.61	49	34.78	40	36.52	42
Total	100.00	115	100.00	115	100.00	115

Given their openness to switching to natural gas, Figure 3 shows that compatibility of machines and equipment was the top consideration for economic zone firms to switch to natural gas. This gives us an indicator that the use of natural gas is more feasible among firms that operate boilers and other heating equipment in their production process. Firms which mainly depend on electricity for their operations are unlikely to shift to natural gas.

Figure 3. Top considerations for fuel switching

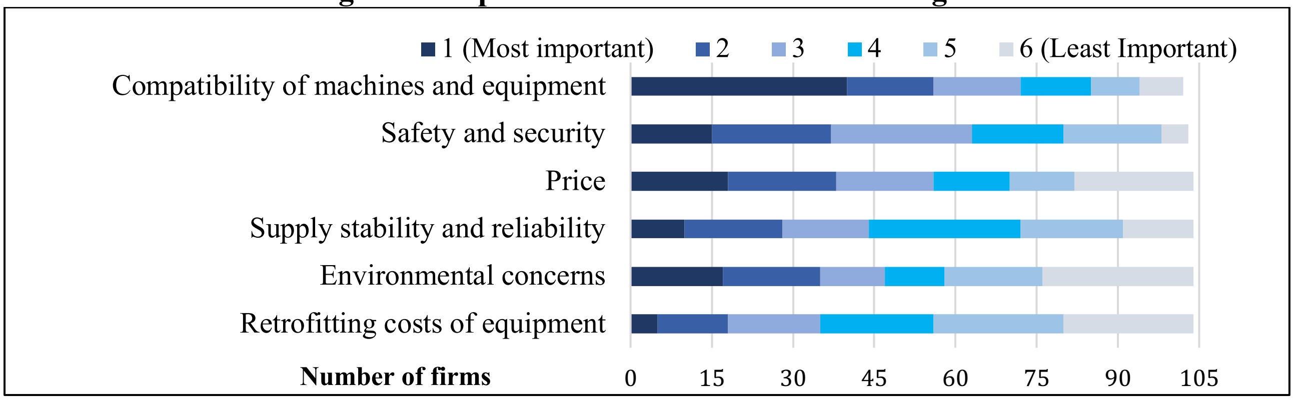


Table 4 provides information on what fuel will likely be replaced when natural gas becomes available. As expected, out of 73 firms with production process, 24 firms indicated they will replace the more expensive diesel, and 15 firms said they will replace LPG with natural gas.

Table 4. Fuels to be replaced by natural gas in case of switching, by number of firms

	In production processes	In self-generation	In back-up power generation
Biodiesel	9	4	7
Bunker	2	1	1
Coal	2	3	3
Diesel	24	31	36
Gasoline	11	11	14
Kerosene	1	1	3
LPG	15	8	6
Propane	1	1	2
Solar	—	10	12
Wind	—	1	1
Other*	18	13	8
Total^	73	73	73

Note: *Argon, electricity, biomass, not applicable, none; ^Total number also includes firms that only use electricity in their production processes.

4.3. Methodology

We investigate the factors that determine firms' propensity to switch to natural gas as fuel in their production processes. Given that we have information on who are open and not open to switch, we employed a logistical regression or *logit* model to explain the probability of switching (switch=1) of firms. Equation (1) presents our model specification. The left-hand side takes on the value 1 when the firm-respondent is open to switch to natural gas, and 0 otherwise. The *logit* model is represented by:

$$\Pr(\mathrm{Y} = 1|\mathrm{X}, \mathrm{N}, \alpha, \beta) = \frac{\exp{(\alpha N + \beta X + u)}}{1 + \exp{(\alpha N + \beta X + u)}} \qquad (1)$$

where *N* represents firms' perceptions and knowledge about natural gas. We control for initial conditions of firms, denoted by *X*. This includes presence of heating in production process, perceived relative cost-competitiveness of natural gas, extent of knowledge on natural gas, electricity expenditure, company size, ecozone type, production sales, per-capita production sales, and whether firms source their electricity from Meralco or any electric cooperative. The error term is represented by u.

As secondary analysis, we also employ a linear probability model by conducting an ordinary least squares (OLS) specification. Table 5 below presents the summary statistics of the variables used in the regression analyses, their descriptions, and units of measure.

Table 5. Summary statistics

Variable	Description	Unit	N	Mean	SD	Min	Max
Openness to Switch	1 if firm is open to switch to natural gas in its production processes, self-generation, and back-up generation of power; 0 otherwise	Binary	115	0.63	0.48	0.00	1.00
Heating	1 if firm has heating component in its production process; 0 otherwise	Binary	115	0.24	0.43	0.00	1.00
Cost-competitiveness	Perceived cost-competitiveness of natural gas relative to other fuels/ energies currently used	Binary	115	0.65	0.48	0.00	1.00
Knowledge	Extent of knowledge on natural gas; 1 if less knowledgeable; 2 if more knowledgeable		115	1.11	0.32	1.00	2.00
Electricity Expenditure	Average monthly electricity expenditure	Thou PhP	115	3,917	7,029	500	45,000
Ln (Electricity Expenditure)	Natural log of monthly electricity expenditure	% point	115	14.09	1.35	13.12	17.62
Company Size	Number of personnel	capita	115	494	964.	4	6,000
Ln (Company Size)	Natural log of company size	% point	115	4.76	1.79	1.39	8.70
Ecozone Type	0 if firm is in a private ecozone; 1 if in a public		115	0.09	0.28	0.00	1.00
Production Sales	Annual production sales in 2018	In Mn PhP	115	3,990	9,070	100	50,000
Per-capita Production Sales	2018 production sales divided by number of personnel	In Thou PhP	115	19,000	112,000	39	1,190,000
Ln (Per-capita Production Sales)	Natural log of per-capita production sales	% point	115	15.06	1.55	10.57	20.90
Meralco or Electric Cooperative	1 if firm sources electricity from Meralco or any electric cooperative; 0 otherwise		115	0.70	0.46	0.00	1.00

5. Results and Discussion

5.1. Likelihood of switching to natural gas

We performed a t-test to determine whether there is a significant difference between the average characteristics of firms who are open and not open to switch to natural gas across various categories (Table 6). There are 42 firms who are not open to switch and 73 firms who are open to switch. In terms of the perception on cost-competitiveness of natural gas (row [2]) and extent of knowledge (row [3]), there is a significant difference between the means of the two groups as evident by an almost zero p-value. Using the 1-5 scale with 5 being "advanced knowledge," the extent of knowledge about natural gas is higher for companies who are willing to switch (mean = 0.49). Likewise, companies that are open to switch also think that natural gas is cost-competitive than the fuels they are currently using.

In terms of the presence of heating production component, ecozone type, whether firms source electricity from Meralco or any electric cooperative, and natural logs of electricity expenditure, company size, and per-capita production sales, there are little to no significant differences between the means of the companies who are willing to switch and those who are not.

Table 6. Openness to switch to natural gas, two-sample t-test

	Variable	T-statistic	Degrees of freedom	P-value	Not open to switch		Open to switch	
					N	Mean	N	Mean
[1]	*Heating*	-0.10	113	0.92	42	0.24	73	0.25
[2]	*Cost-competitiveness*	-3.57	113	0.00	42	0.45	73	0.77
[3]	*Knowledge*	-2.47	113	0.01	42	0.26	73	0.49
[4]	*Ln (Electricity Expenditure)*	0.03	113	0.97	42	14.09	73	14.09
[5]	*Ln (Company Size)*	0.78	113	0.44	42	4.93	73	4.66
[6]	*Ecozone Type*	0.92	113	0.36	42	0.12	73	0.07
[7]	*Ln (Per-capita Production Sales)*	-0.81	113	0.42	42	14.90	73	15.15
[8]	*Meralco or Electric Cooperative*	0.18	113	0.86	42	0.71	73	0.70

Significant difference between the means of the two group of firms, those who are open and not open to switch, in terms of perception on cost-competitiveness of natural gas and extent of knowledge.

In order to examine the factors that predispose a firm to switch to natural gas, we employ both a logistic regression (*logit*) model and a linear probability model using OLS. Regressors in these models include indicators whether heating was used in the firm's production process and whether they believe that natural gas is cost-competitive. We also include an indicator on the extent of knowledge on natural gas, whether the firm sources electricity from Meralco or any electric cooperative, as well as the type of ecozone, whether public or private. We also include variables on the size of the firm in terms of employment, sales, and electricity expenditure.

The results of the *logit* model and OLS estimates are presented in Table 7. Column [1] of Table 7 presents the estimates using logistic regression in odds ratio units. Column [2] presents the marginal effects at the means (MEM). The results of the MEM estimates show that firms have a higher predictive probability to switch when they have heating component in their production processes and perceived natural gas to be more cost-competitive relative to their existing fuels (*Heating* = 1; *Cost-competitiveness* = 1). Specifically, the predictive probability for these firms to switch to natural gas are higher by 39.8 percentage points (= 78.3% – 38.5%) compared to a firm with heating but do not believe natural gas to be cost-competitive, holding all other variables at their means. For those with no heating component (*Heating* = 0), the predictive probability of switching is 30 percentage points (= 74.8% – 44.8%) higher for those who think natural gas is more competitive (*Cost-competitiveness* = 1) than those who think otherwise (*Cost-competitiveness* = 0), holding all other variables at their means.

Table 7. What would influence firms to switch to natural gas?

Dependent variable: *Open to switch = 1; Not open = 0*	Logistic Regression		OLS Regression
	Odds Ratio	Margins	
	[1]	[2]	[3]
Heating = 0; *Cost-competitiveness* = 0	1.293	0.448**	0.450**
	(1.043)	(0.096)	(0.085)
Heating = 0; *Cost-competitiveness* = 1	4.730*	0.748**	0.733**
	(3.662)	(0.060)	(0.062)
Heating = 1; *Cost-competitiveness* = 0	—	0.385*	0.392*
		(0.166)	(0.153)
Heating = 1; *Cost-competitiveness* = 1	5.750	0.783**	0.768**
	(5.340)	(0.102)	(0.112)
Knowledge = 0	—	0.564**	0.559**
		(0.065)	(0.058)
Knowledge = 1	2.582*	0.770**	0.745**
	(1.175)	(0.065)	(0.068)
Ln (*Electricity Expenditure*)	1.251	0.051	0.044
	(0.307)	(0.055)	(0.050)
Ln (*Company Size*)	0.795	-0.052	-0.046
	(0.155)	(0.044)	(0.039)
Ecozone Type = 0 (Private)	—	0.666**	0.645**
		(0.050)	(0.045)
Ecozone Type = 1 (Public)	0.588	0.540**	0.531**
	(0.459)	(0.185)	(0.154)
Ln (*Per-capita Production Sales*)	0.971	-0.007	-0.006
	(0.153)	(0.036)	(0.031)
Meralco or Electric Cooperative = 0	—	0.713**	0.686**
		(0.095)	(0.091)
Meralco or Electric Cooperative = 1	0.688	0.631**	0.614**
	(0.396)	(0.063)	(0.055)
Constant	0.115	0.115	0.073
	(0.451)	(0.451)	(0.791)
Pseudo R-squared / R-squared	0.123	0.126	0.158
N	115	115	115

Note: * $p<0.05$; ** $p<0.01$. Margins are marginal effects at the means using the Stata command "margins, dydx(*) atmeans"

In terms of knowledge extent (Column [2]), more knowledgeable firms have 20.6 percentage points (= 77% – 56.4%) higher predictive probability of switching than less knowledgeable firms, holding all other variables at their means. By type of ecozone, firms in private ecozones have 12.6 percentage points (= 66.6% – 54%) higher predictive probability of switching than firms in public ecozones, holding other variables at their means. In terms of sources of electricity, firms who get their electricity from other sources, such as direct from generation companies through retail competition and open access (RCOA), have 8.2 percentage points (= 71.3% – 63.1%) higher predictive probability of switching than those who get their electricity supply from Meralco or cooperatives, holding all other variables at their means. The other covariates, natural logarithm of electricity expenditure, company size, and per-capita production sales do not significantly affect the firm's openness to switch.

The results of our secondary analysis using OLS is presented in Column [3]. The results show that a firm with heating component in their production processes and perceived natural gas to be more cost-competitive relative to their existing fuels (*Heating* = 1; *Cost-competitiveness* = 1), are 37.6 percentage points (= 76.8% – 39.2%) more likely to switch to natural gas compared to a firm with heating but do not believe natural gas to be cost-competitive (*Heating* = 1; *Cost-competitiveness* = 0). In addition, there is a strong correlation between cost-competitiveness and openness to switch among firms with no heating component in their production processes. For firms with no heating component, those who think natural gas is cost-competitive are 28.3 percentage points (= 73.3% – 45.0%) more likely to switch than those who think otherwise. Furthermore, firms who are relatively more knowledgeable on natural gas are more likely to switch to natural gas than those with limited knowledge. More knowledgeable firms are 18.6 percentage points (= 74.5% – 55.9%) more likely to switch than less knowledgeable firms. Moreover, firms within private ecozones are, on average, 11.4 percentage points (= 64.5% – 53.1%) more likely to switch than firms within public ecozones. In terms of electricity source, firms that do not source electricity from Meralco or any electric cooperative are 7.2 percentage points (= 68.6% – 61.4%) more likely to switch than firms that do.

In summary, our robust results show switching to natural gas involves both knowledge and the technology employed in the production process. Crucial to increasing the probability of switching is the extent of knowledge about natural gas, that it is cost competitive, that firms use heating in their production process, type of ecozone firms are in, and electricity provider. Hence, energy-intensive manufacturing firms with more expensive fuel sources are more likely to switch.

Given the results above, we determine which among the SEZs are more likely to switch considering the type of firms operating in their area. We do this by computing the predicted likelihood of switching of each firm using the parameter estimates from Table 7. We then sum up the predicted value, weighted by the firms' size per ecozone. Table 8 presents the results of predicted likelihood of switching by ecozone in our sample. The estimates using *logit* and OLS resulted in almost the same ranking of SEZs. Keppel Philippines Marine SEZ ranks first in the likelihood to switch at 83.14% (Column [1]), followed by Greenfield Automotive Park (81.02). SEZs that are least likely to switch are Victoria Wave Special Economic Zone at 24.73%, followed Mactan Economic Zone (33.38%) and Pampanga Economic Zone (35.65%).

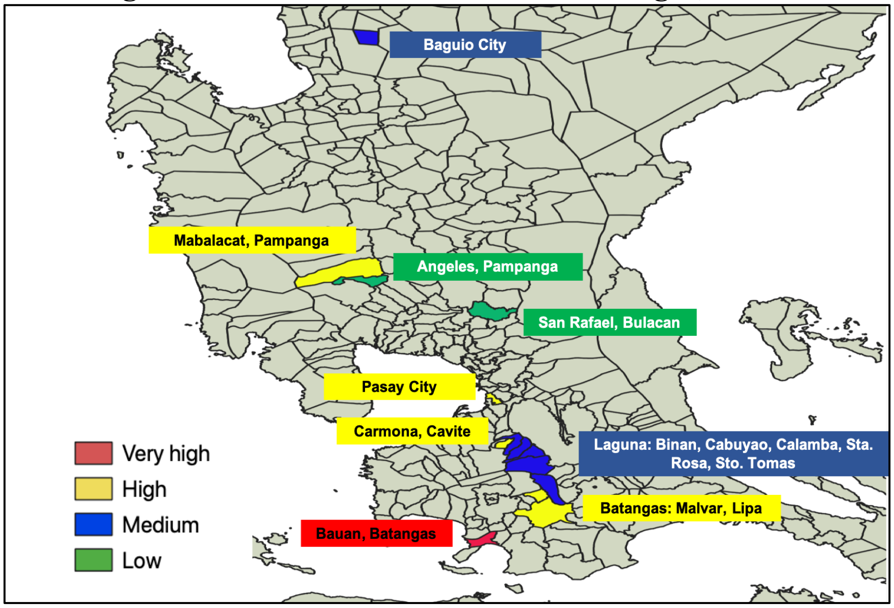
Table 8. Likelihood to switch to natural gas, ranking by SEZs

Ecozone	Municipality, Province	Logit		OLS	
		Weighted Mean (%)	Rank	Weighted Mean (%)	Rank
		[1]	[2]	[3]	[4]
Keppel Philippines Marine SEZ	Bauan, Batangas	83.14	1	83.04	1
Greenfield Automotive Park	Sta. Rosa, Laguna	81.02	2	80.80	2
Laguna Technopark Annex	Biñan, Laguna	78.91	3	77.87	3
MacroAsia Ecozone	Pasay	76.61	4	75.44	4
Laguna International Industrial Park	Biñan, Laguna	74.94	5	73.84	5
Cebu Light Industrial Park	Lapu-Lapu, Cebu	73.16	6	73.48	6
Lima Technology Center	Malvar and Lipa, Batangas	68.76	7	68.99	7
West Cebu Industrial Park	Balamban, Cebu	67.49	8	66.86	8
Golden Mile Business Park	Carmona, Cavite	66.28	9	64.79	9
TECO Industrial Park	Mabalacat, Pampanga	65.37	10	64.18	10
Calamba Premiere International Park	Calamba, Laguna	62.85	11	62.81	11
First Philippine Industry Park	Sto. Tomas, Batangas	58.80	14	60.42	12
People's Technology Complex	Carmona, Cavite	58.75	15	59.43	13
Filinvest Technology Park Calamba	Calamba, Laguna	59.26	13	58.57	14
Golden Gate Business Park – Cavite Export Processing Zone	Carmona, Cavite	60.53	12	57.81	15
Carmelray Industrial Park II	Calamba, Laguna	58.16	16	57.25	16
Baguio City Economic Zone	Baguio, Benguet	56.98	17	56.08	17
Light Industry & Science Park I	Cabuyao, Laguna	52.43	18	52.38	18
Laguna Technopark SEZ	Sta. Rosa and Biñan, Laguna	49.65	19	49.08	19
Light Industry & Science Park II	Calamba, Laguna	44.63	20	45.07	20
Toyota Sta. Rosa (Laguna) SEZ	Sta. Rosa, Laguna	42.47	21	42.15	21
Pampanga Economic Zone	Angeles, Pampanga	35.65	22	36.68	22
Mactan Economic Zone	Lapu-Lapu, Cebu	33.38	23	34.25	23
Victoria Wave SEZ	San Rafael, Bulacan	24.73	24	26.72	24

Note: Ranking covers only SEZs in our sample.

Figure 4 below provides a visual presentation of the probability of switching by city or municipality categorized by “very high,” “high,” “medium,” and “low” in Luzon islands. Figure 4 shows that SEZs in Bauan, Batangas are very highly likely (red color) to consider natural gas as fuel followed by highly-likely-to-switch (yellow color) in Malvar and Lipa, Batangas. Pasay; Balamban, Cebu; Carmona, Cavite; and Mabalacat, Pampanga SEZs are also highly likely to switch to natural gas. SEZs in Angeles, Pampanga, and San Rafael, Bulacan on average, consider natural gas as a feasible fuel but at a low likelihood (green color).

Figure 4. Likelihood to switch to natural gas, Luzon



5.2. Natural gas as a bridge fuel in an efficient transition to cleaner energy

An efficient energy transition involves moving to energy sources with the least social costs including pollution damages. A dynamic calculation should also take into account the declining costs of wind and solar power and the low costs of managing intermittency (Heal, 2017). In order for the decisions of private investors to be consistent with least social costs, taxes should reflect the marginal damage costs of pollution, especially from generation with coal.

Taking the role as a bridge fuel, natural gas can help facilitate the efficient transition to cleaner energy. Pollutants from dirtier fossil fuels not only harm the environment but also cause serious respiratory health problems. The estimated monetary cost of all damages emanating from local pollutants can be substantial, insofar as these induce respiratory problems including coughing, wheezing, etc. (Jandoc et al., 2018). There are several ways in which natural gas reduces damages: First, if the firm uses diesel in the production process and switches to natural gas, there is a reduction in harm. Second, if natural gas can be used as fuel in generating electricity inside the SEZs, damage cost associated with the use of diesel, oil, and coal in generating electricity could potentially be avoided. Switching to electricity generation using natural gas is possible, especially if the natural gas power plant is located inside the SEZ and is able to offer a lower rate than their current electricity distribution utility outside of the SEZs. In Table 9, we conducted a back-of-the-envelope calculation of the avoided damage cost should diesel be replaced by natural gas in the heating process and should coal be replaced by natural gas in electricity generation.

For those 73 firms that are open to switch and currently sourcing their electricity from a utility outside of SEZs, the total marginal avoided damage cost of SO2, NOx, and PM2.5 are USD 566, USD 40, and USD 69 per MWh, respectively. For those who are using diesel in their production processes and are open to switch, the total marginal avoided damage cost of SO2, NOx, and PM2.5 are USD 4, USD 12, and USD 0.37 per MWh, respectively.

Table 9. Marginal damage cost of local pollutants per MWh of electricity produced from fuel

Fuel	Fuel consumption (liter) [A]	Electricity produced per fuel (MWh/unit of fuel) [B]	Total electricity consumption from fuel (MWh) [A x B = C]	Marginal damage cost of local pollutant (in USD per MWh) [D]			Total marginal damage cost of local pollutant (in USD per MWh) [C x D = E]		
				SO2	NOx	PM2.5	SO2	NOx	PM2.5
Coal *	—	—	38.33 ***	14.76	1.05	1.79	565.77	40.25	68.61
Diesel **	287.43	0.01	3.06	1.16	4.06	0.12	3.55	12.41	0.37

Notes: Calculations are based only on firms willing to switch to natural gas (N = 73). *N_{coal} = 51; **N_{diesel} = 15; *** Value is computed based on firms' electricity consumption from Meralco. Authors use 31.05% as the percentage of coal in Meralco's electricity generation mix.

6. Concluding Remarks

The aim of our study is to gauge the extent of the potential demand for natural gas among firms of the ecozones. We first identify firms who are likely to switch to natural gas if this becomes available. Currently, firms' energy demand is met by electric distribution utilities and/or power generation units based on fuels other than natural gas. We then gauge their awareness of the natural gas potential for their respective firms and their willingness to switch. We confirm that the potential is greatest among firms that require intense heat for their production such as boilers, which is generated by burning less environmentally friendly fuels (e.g. diesel or coal) other than natural gas. We confirm that switching is least likely among firms whose power needs are supplied by electric utilities.

Price, supply stability and reliability, and environmental concerns are among the top considerations for firms who show willingness to switch to natural gas. Price offered to the end-user would be influenced by several factors including the LNG virtual pipeline delivery system; the capital and operating expenditures of satellite or the small-scale LNG storage and regasification terminals to be located inside the SEZs; among others. Naturally, firms also take into account the upfront capital cost of switching including the stranding cost of replaced equipment, all of which may protract the decision to switch.

While the study covers only manufacturing and agro-industrial firms in ecozones, the results provides an indication that markets for natural gas outside of electricity generation exist. It also provides a gauge of the minimum size of the market and illustrates a greater market potential given the number of manufacturing and agro-industrial firms outside of ecozones. Our survey and methodology offer potential to scale the size of data collection to include other firms outside the special economic zones.

With economic growth, natural gas as an alternate energy source would also allow for more competitive electricity costs owing to the current oversupply of natural gas in the world market and the relative ease of transport given the liquefaction technology. Furthermore, natural gas could play a crucial role in lowering the Philippines' carbon emissions given that natural gas emits 60% less carbon dioxide than coal. The use of natural gas is also an important step in the efficient transition to a more renewable future as it can potentially ease the intermittency problem of solar and wind through its quick start-up and shutdown capacity (Anderson and Leach, 2004; Lee et al., 2012).

From a policy point of view, the results of our study suggest a potential growing market for LNG in the Philippines in addition to the requirement to fill the need due to the depletion of Malampaya gas field. The LNG industry is responding thus, its development should be nurtured by appropriate regulation. There will also be a need for more intense information drive on the minutiae of switching if and when natural gas becomes available.

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