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Electricity subsidy reform in Indonesia: Demand-side effects on electricity use

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Abstract: Indonesia's budget has for years been burdened by large subsidies for electricity consumption. A series of recent reforms has delivered a substantial reduction in these subsidies. In this paper we estimate demand-side effects of these reforms on electricity use. Our analysis utilizes a three-dimensional dataset covering six consumer groups, 16 regions, and 1992–2015. We control for various fixed effects, and use an instrumental variable approach. Our estimates suggest that subsidy reductions since 2013 had induced savings in annual electricity use of around 7% relative to the no-reform counterfactual as of 2015. The phase-out of remaining subsidies has the potential to generate further improvements in the efficiency of electricity use, while freeing up resources for other priorities such as infrastructure spending.

JEL codes: Q41, Q48, L94

Keywords: electricity subsidy, electricity demand, price elasticity, Indonesia, panel data

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1. Introduction

Indonesia, with a population exceeding 258 million people, has recently pursued one of the world's most ambitious programs of electricity subsidy reforms. In this study we use panel data for 1992–2015 to estimate the price elasticity of demand for electricity in Indonesia. We use our estimates to quantify the demand-side effects of Indonesia's electricity subsidy reforms on electricity use. Our dataset covers six consumer groups – residences, business, industry, social services, government buildings, and public street lights – and 16 regions.

Indonesia's history of subsidies for the consumption of electricity is a long one (McCawley, 1970; Kristov, 1995; Soesastro and Atje, 2005; Burke and Resosudarmo, 2012). The subsidies result from electricity tariffs that have been set at a level below the cost of supplying electricity. The taxpayer has been required to make up the difference, via subsidy payments to the electricity utility *Perusahaan Listrik Negara* (PLN). Infrequent increases in electricity tariffs, together with strong growth in electricity use and increases in the cost of supplying electricity, saw the official value of Indonesia's annual electricity subsidy expenditure balloon to 95 trillion IDR (US$10 billion) in 2012. This was an on-budget expense item for the national government that equalled 6% of the value of central government expenditure and transfers, and 1% of gross domestic product (CEIC, 2016). According to the International Monetary Fund's (2015) pre-tax measure, in 2013 Indonesia had the world's 4th-largest electricity subsidies in US dollar terms, after Russia, Iran, and Saudi Arabia. By "subsidy" we refer to electricity consumption subsidies associated with below-cost electricity tariffs (not government spending on electricity infrastructure).

Indonesia's electricity subsidies have been notionally justified by reasons such as assisting the poor, aiding industrial competiveness, and helping to stabilize prices. The subsidies have been poorly targeted, however, with the well-off receiving a large share. Financial difficulties caused by low electricity tariffs have also reduced the direct incentive for PLN to expand access to less-serviced areas. Subsidizing electricity is likely to encourage inefficient electricity use and excessive emissions in the process of electricity generation.

In recent years Indonesia has introduced a series of historic reforms to electricity tariffs in an attempt to reduce the size of its electricity subsidies. The reforms are consistent with Electricity Law No. 30/2009, which requires the government to connect underserviced areas to electricity and supply electricity to the poor, but does not envision broad subsidies for electricity use. Relatively large increases in electricity tariffs have been phased in since 2013,

with subsidies now fully eliminated for some consumers. The bulk of remaining subsidies flow to residences. The reforms were implemented both during the final years of the Yudhoyono presidency and the first years of the Widodo presidency. Subsidies for the consumption of gasoline and diesel for transport have also been reduced (Yusuf et al., 2016).

Reductions in electricity subsidies should be expected to provide an attractive means of improving the efficiency with which electricity is used. This is because high-value uses of electricity will proceed even after consumers shift to paying a cost-reflective price. Improved efficiency of electricity use in turn alleviates the need for supply-side investments. Electricity infrastructure is expensive: the announced cost of Indonesia's ongoing 35 gigawatt capacity expansion project was more than 1,100 trillion IDR (US$82 billion; PLN, 2016b). Phasing out fossil fuel subsidies is a key commitment of the international community, as pledged by the G20 and Asia-Pacific Economic Cooperation (APEC) in 2009. Indonesia's electricity generation is predominantly fossil-fuel based, with coal (56% of electricity generation in 2015), natural gas (25%), and oil (8%) dominating the mix (International Energy Agency [IEA], 2017a). Hydro (6% of generation) and geothermal (4%) also make quite important contributions.

In estimating the short-run price elasticity of electricity demand, we use two strategies to control for non-price factors – both supply-side and demand-side – that potentially affect electricity use and that are also potentially correlated with electricity prices. The first is to include a set of observed controls. The second is to control for multiple dimensions of fixed effects. In our three-dimensional panel we control for factors common to consumer groups in any region (across all years), regions in any year (across all consumer groups), and consumer groups in any year (across all regions). Identification is also aided by the observation that the timing of and motivation for electricity tariff decisions have been largely determined by budgetary and political considerations. The timing and scale of changes to electricity tariffs have also varied by consumer group. In addition, we pursue an instrumental variable (IV) approach that exploits the three-dimensional nature of our study setting.

We find that electricity demand in Indonesia is price inelastic, with a same-year elasticity of demand of –0.15 to –0.2 and a four-year elasticity of around –0.4. That the elasticity is negative implies Indonesia's subsidy reforms are contributing to demand-side savings in electricity use even in the relatively short run, of a magnitude that we will quantify. Our estimates will be able to assist the planning and budgeting of both PLN and Indonesia's government. They are of potential use to other developing countries, especially those embarking on reforms to electricity tariffs.

This paper provides the first known estimates of the price elasticity of aggregate electricity demand in Indonesia. The estimates add to findings from other countries. Khanna and Rao (2009) reviewed studies from developing countries, observing that the mean short-and long-run price elasticities of electricity demand are –0.4 and –0.6. Espey and Espey (2004) carried out a meta-analysis of studies of residential electricity demand, reporting a mean short-run price elasticity of demand of –0.35, and a long-run elasticity of –0.85. Zhang (2014) concluded that electricity price increases have been important for industrial energy efficiency improvements in China, consistent with our finding for Indonesia. Wang and Lin (2017) estimated the potential effects of electricity subsidy reform for China's residential sector, concluding that substantial demand-side electricity savings would occur if the subsidies were phased out. Our findings also concur with the household survey findings of Wijayapala and Kankanamge (2016) for Sri Lanka, who concluded that electricity subsidies encourage households to use inefficient equipment such as incandescent lamps. Our research complements the work by Burke et al. (2017) on the effect of the concurrent reforms to Indonesia's subsidies for gasoline and diesel on traffic flows on Indonesian toll roads.

The remainder of the paper proceeds as follows. Section 2 provides an overview of Indonesia's electricity sector. Section 3 sets out our models and data. Section 4 presents the results. Section 5 concludes.

2. Indonesia's electricity sector

In 2014 Indonesia was the world's 21st-largest consumer of electricity and, due to high reliance on coal, the 11th-largest emitter of carbon dioxide emissions from the generation of electricity and heat (IEA, 2017a, 2017b). Indonesia is a relatively small electricity consumer on a per capita basis, however, with use equal to only around a quarter of the world average (World Bank, 2016). Electricity contributed 11% of final energy use in Indonesia in 2015 (in oil equivalent terms). This is much less than the contribution of electricity to final energy use in China (22%). Indonesia has higher reliance on oil-based fuels, solid biomass, and natural gas as final energy sources (IEA, 2017a).

There is substantial geographical variation in electricity use within Indonesia. Java, home to 57% of Indonesia's population, accounted for 72% of electricity sales in 2016 (PLN, 2016a). The household electrification rate is also highest in Java (94%), although with some variation between provinces. Papua has the lowest electrification rate among Indonesia's provinces, at less than 40% in 2016. The national household electrification rate had risen to 89% as of 2016 (PLN, 2016a), up from 64% in 2009 (PLN, 2009) and 53% in 1995 (Asian Development Bank, 2016). The government has the aim of reaching a national household electrification rate of 97% by 2019 (PLN, 2015a).

The average electricity user in Indonesia faced 81 hours without electricity in 2008 (PLN, 2011) as a result of rolling blackouts from a supply system that was struggling to meet demand. This fell to only 5 hours in 2015. In 2015 Indonesia scored 4.1 out of 7 for the quality of its electricity supply on a World Economic Forum (2015) survey of business executives, placing 86th among 140 countries. The score was up from 3.5 in 2006. Sambodo (2016, p. 39) nevertheless reports some regions are in a "power crisis". Blackouts cause large economic costs (PwC, 2016).

Electricity prices in Indonesia are set by the government, and vary by consumer group and sub-group. Consumers are billed monthly, and face both fixed charges and utilization tariffs. These are typically higher for consumers with larger power connections, measured in volt-ampere (VA). Many consumers face increasing block tariff structures, meaning that they pay a higher marginal per kilowatt hour (kWh) tariff at higher usage levels. Some consumers face a minimum monthly electricity bill; their effective marginal price is zero when electricity consumption is below the minimum threshold. In recent years, consumers have had the option to prepay their electricity bills. Electricity Law No. 30/2009 allows regional differentiation in tariffs; the two small regions of Batam and Tarakan apply their own tariff schedules (World Bank, 2005).

An example of Indonesia's electricity tariff schedules will help. Let us consider residential consumers. As of May 2014, residences with connections of 450 VA (R-1) faced a block pricing schedule, with a monthly fixed charge of 11 IDR per VA of installed capacity and the following utilization tariffs: 169 IDR per kWh for the first 30 kWh during a month; 360 IDR per kWh for units of usage in the 30–60 kWh range; and 495 IDR for each kWh above 60 kWh. There was the option to prepay at 415 IDR per kWh. There are several additional tariff classes for residences with larger connections. Residences with the largest connections (6,600 VA or above) faced an unsubsidized tariff of 1,352 IDR per kWh, with a minimum monthly payment.

Fig. 1 presents the average annual electricity price paid by each consumer group during 1992–2015, in nominal terms. Changes in the average electricity price are a result of changes in the (a) tariff schedule, (b) composition of electricity consumption by a consumer group, and (c) success of PLN revenue collection.

As can be seen in Fig. 1, electricity tariffs were raised after the Asian financial crisis (AFC) of the late 1990s. This was a time of relatively high inflation, including in PLN's production costs. Tariff schedules were then left unchanged over 2004–2009. These were years of policy uncertainty after the 2002 Electricity Law was ruled unconstitutional. Following the introduction of the new Electricity Law, in 2010 electricity tariffs were again raised for some

tariff classes. Recent reforms commenced with Ministry of Energy and Mineral Resources Regulation No. 30-2012, which slated quarterly increases in key tariffs in 2013. Further increases were implemented in 2014 and 2015. A system of automatic monthly adjustments was also re-introduced for tariff classes for which electricity subsidies have been withdrawn.

Fig. 1. Average electricity price by consumer group in Indonesia, 1992–2015
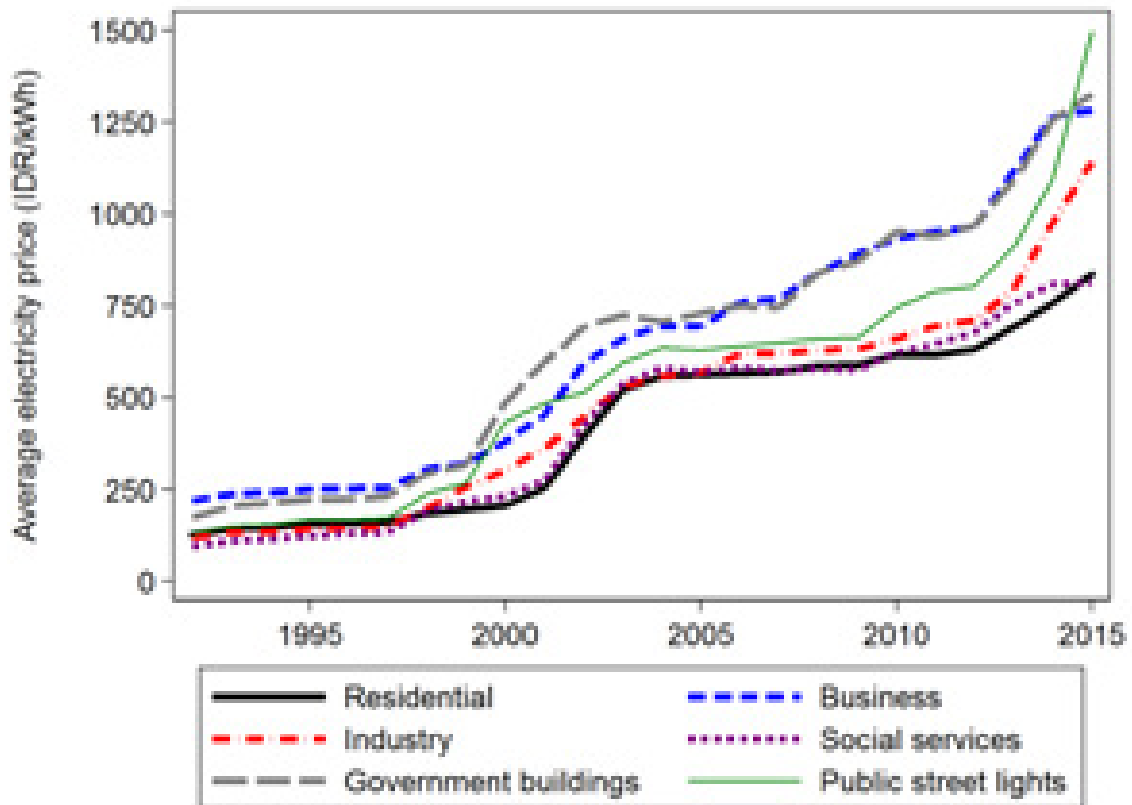

Notes: Average electricity price is collected revenue per kWh, in nominal terms. Sources: BPS (1997, 2001), CEIC (2016).

Not all tariff rates were affected by the electricity subsidy reforms; tariffs for consumers with connections of up to 900 VA – i.e. most households, plus small enterprises – indeed remained unchanged from 2003 until the end of our study period. As of 2016, it was calculated that more than 70% of households received subsidized electricity (Global Subsidy Initiative, 2016). Indonesia's official poverty rate was only 11% (BPS, 2016), meaning that many people received electricity subsidies even though they were not poor.

Fig. 1 also shows that residences and social services tend to pay the lowest electricity prices. The highest prices are paid for electricity use by public street lights, government buildings, and business. In 2013 the largest increase in average electricity price was for business (16%). In 2014, it was for industry (23%). In 2015, public street lights (36%).

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Fig. 2 shows electricity use by consumer group for 1992–2015, based on sales of PLN. Residences accounted for 43.7% of electricity use in 2015, industry for 31.6%, and business 18.2%. Social services (2.9%), government buildings (1.8%), and public street lights (1.7%) accounted for the remainder. Growth in residential electricity use has in part been due to Indonesia's scaling up of electricity access. Annual growth in national electricity use was only 2.1% in 2015, the slowest rate since 1998. We find that this slow rate is largely a result of Indonesia's electricity subsidy reforms.

Fig. 2. Electricity consumption by consumer group in Indonesia, 1992–2015
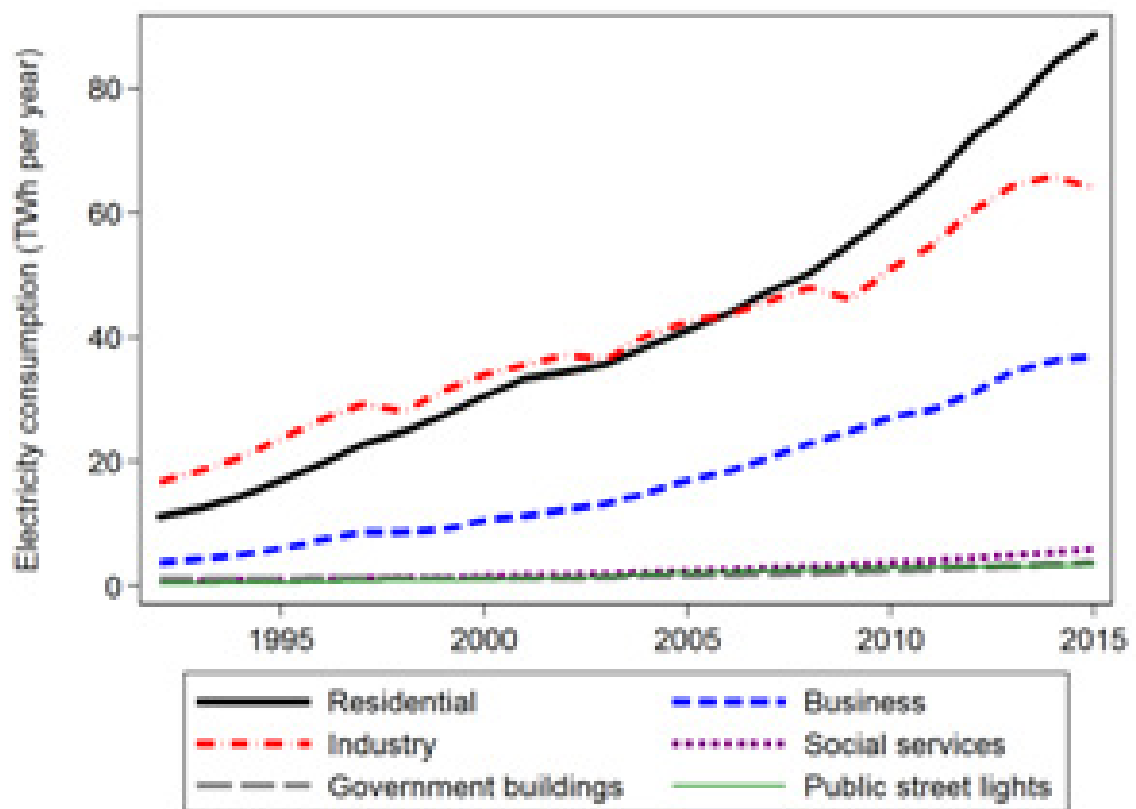
Notes: Consumption is measured using PLN sales quantities. Does not include captive generation and (minor) non-PLN sales. Sources: BPS (1997, 2001), CEIC (2016).

The measure of electricity consumption that we use does not include captive generation for own-use. Captive generation – often by diesel generator, but also using other technologies – is relatively prominent in Indonesia, typically to reduce risks to electricity supply or to secure access in locations where on-grid supply is not available. In 2014 around 97% of hospitals, 92% of shopping centers, and 61% of hotels were estimated to use captive electricity (*Badan Pusat Statistik* [BPS], 2015a). On average, captive sources were estimated to account for 19%, 7%, and 56% of the electricity consumed by these establishments.

Fig. 3 shows data on official electricity subsidy spending over 2000–2015, in nominal terms. A large ramp-up from 2004 is visible, with a peak in 2014. This increase is in part due to improvements to the transparency of electricity subsidies; historically, the subsidies were delivered somewhat more opaquely in the form of capital and other injections to PLN (McCawley, 1970). It is nevertheless fair to say that the Yudhoyono presidency (2004–2014) saw a large overall ramp-up in electricity subsidy spending. Some of the efforts to increase electricity tariffs during this time were frustrated by Indonesia's parliament.

Fig. 3. On-budget electricity subsidies in Indonesia, 2000–2017
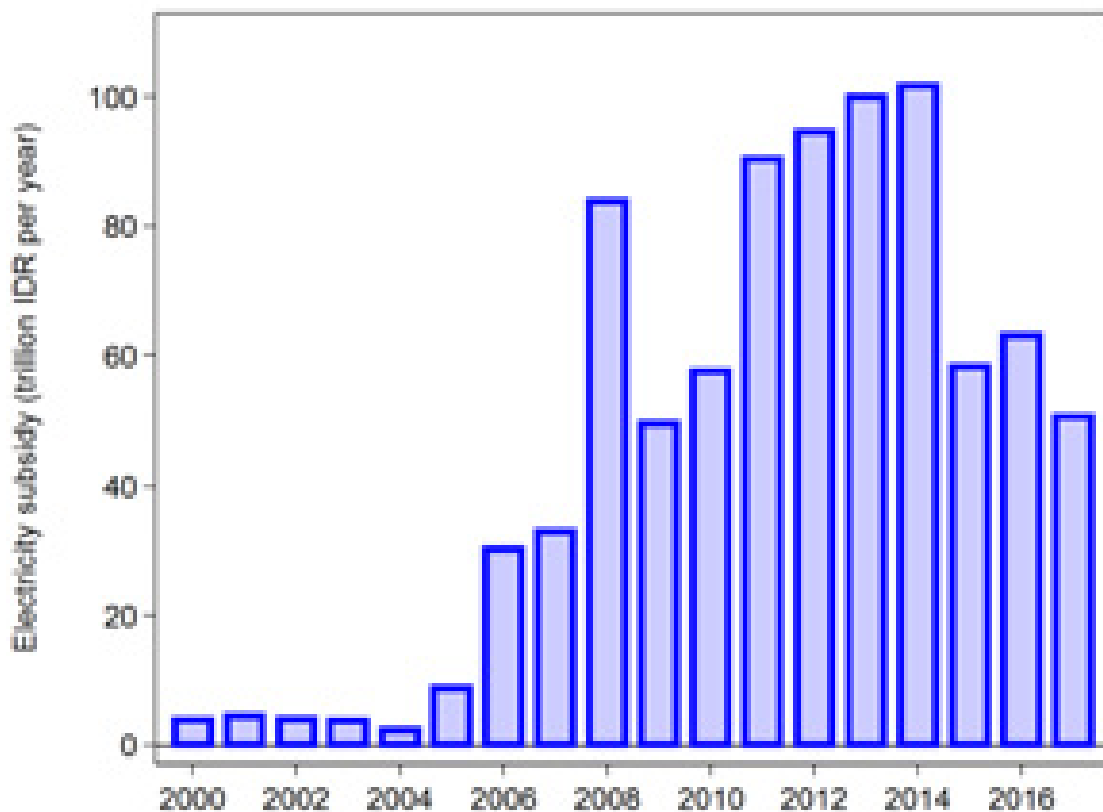
Notes: On-budget operational electricity subsidy expenditure, in nominal terms. Currently includes a margin of 7% for PLN. Does not include capital injections. 2017: preliminary figure. Sources: Data for the central budget from the Ministry of Finance (pers. comm.; 2016), Howes and Davies (2014), Indonesia-Investments (2018).

Aided by reductions in the cost of generating electricity as well as increases in electricity tariffs, Indonesia's electricity subsidy spending fell by more than 40% in 2015 relative to 2014. Further reforms in 2017 helped to reduce spending on electricity subsidies to around 2% of central government expenditure and transfers.

Unlike some earlier energy subsidy reform episodes, to date there have been no major public protests against Indonesia's recent reforms. Among the apparent reasons for the success are: (a) the exemption of the poor from electricity price increases, and (b) the government's

communication strategies. The latter included social media campaigns and on-campus briefings to student groups by officials from the Ministry of Energy and Mineral Resources.

3. Models and data

3.1 Models

We first carried out unit root tests on the logs of electricity use, the average electricity price, and gross domestic product (GDP) per capita. Using national data, augmented Dickey-Fuller tests (Dickey and Fuller, 1979) with linear time trends were unable to reject the nulls that these variables contain unit roots.[1] We consequently opted to employ models in first-differences. We commence with the following two-dimensional specification:

$$\Delta \ln E_{g,y} = \alpha + \beta \Delta \ln P_{g,y} + \gamma \Delta \ln Y_y + \delta \Delta \ln N_y + \Delta X'_{g,y} \boldsymbol{\theta} + \eta_g + \eta_y + u_{g,y} \tag{1}$$

where $E_{g,y}$ is electricity use of consumer group g in year y, in terawatt hours (TWh). P is the average electricity price, in nominal IDR per kWh. Y is GDP per capita, in IDR. It is important to control for GDP because higher incomes likely boost the demand for electricity. N is population, in people. X is a set of time-varying controls. η_g is a set of consumer group fixed effects to allow for different underlying electricity use trajectories for each consumer group. η_y is a set of year fixed effects to remove the effects of time-specific factors that might affect electricity use, such as macroeconomic shocks, inflation, supply-side extensions to the grid, and Indonesia's subsidy reforms for gasoline and diesel products. η_y is perfectly collinear with Y, N, and some elements of X; we exclude these controls when year fixed effects are included. u is an idiosyncratic error. Δ is the first-difference operator.

Our X vector includes the log diesel price, temperature, logged length of transmission lines, the log system average interruption duration index (SAIDI) as a measure of blackouts, a time trend, and the log number of consumers in each consumer group. Diesel is used for captive generators and other purposes, and is also an input to some generation of on-grid electricity. Temperature is included because demand for air conditioning may be higher in hotter years. The transmission line and SAIDI variables aim to control for supply-side factors affecting electricity consumption. The time trend is included to allow the rate of growth of electricity consumption to evolve as a function of time.

Including the log number of consumers helps to control for the large supply-side expansion in the availability of electricity in Indonesia. This expansion may have been incentivized by higher average electricity prices, creating a potential bias in the absence of this control. A disadvantage of this control is that connecting to electricity is also a function of demand-side

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[1] We selected lag lengths for these tests using the Bayesian information criterion.

decisions, likely to themselves be affected by the electricity price. This control thus might attenuate our estimate of the price elasticity of electricity demand. We present results both including and excluding the log number of consumers.

Using data by region (r), we then proceed to the following three-dimensional specification:

$$\Delta \ln E_{g,r,y} = \alpha + \beta \Delta \ln P_{g,r,y} + \gamma \Delta \ln Y_{r,y} + \delta \Delta \ln N_{r,y} + \Delta X'_{g,r,y} \boldsymbol{\theta} + \eta_{g,r} + \eta_{r,y} + \eta_{g,y} + u_{g,r,y}$$

$$(2)$$

$\eta_{g,r}$ is a set of consumer group*region fixed effects, to allow different trajectories in electricity use in each consumer group in each region. $\eta_{r,y}$ is a set of region*year fixed effects, to control for changes in electricity use emanating from region-specific factors in each year. We exclude observed control variables that vary only by year or by region*year once these region*year fixed effects are included. The effects of extensions to electricity grids will be removed by these fixed effects, assuming the extensions had similar implications for each consumer group. $\eta_{g,y}$ controls for factors influencing electricity use in each consumer group in each year, for example sector-specific shocks to industrial enterprises. We will start by including a sub-set of these fixed effects, then move to the full set. A key motivation for using data by region is that revisions to national electricity tariffs have regionally-varying effects on average electricity prices due to differences in the composition of consumer groups across regions. The approach is similar to that used by Burke and Abayasekara (in press) in a study of the price elasticity of electricity demand in the United States.

We explore a number of additional specifications. These include a one-dimensional time-series estimate for Indonesia's aggregate electricity use; a two-dimensional specification interacting $\Delta \ln P_{g,y}$ with consumer group dummies to estimate separate same-year price elasticities of demand for each consumer group; two-dimensional specifications with additional lags of $\Delta \ln P_{g,y}$ to estimate delayed effects;[2] and specifications that test whether the price elasticity of electricity demand is similar in and outside Java, and whether it has evolved over time. We computed the variance inflation factors for key estimates, obtaining quite low values. We thus conclude that multicollinearity is not a substantial concern.

Our goal is to obtain an accurate estimate of β, which is intended to be the same-year price elasticity of demand.[3] Our controls help to reduce the possibility of omitted variables bias.

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[2] An alternative is to seek a long-run elasticity from a model with a lagged dependent variable (LDV). We prefer to focus on observed responses rather than the implied long-run response embodied in forward simulations of an LDV model. Bias can be problematic in LDV models with short time dimensions (Judson and Owen, 1999).

[3] Our specification is in first differences, but note that it is still true that $d \ln E_t / d \ln Y_t = \beta$.

Given that Indonesia's electricity tariff increases have been politically determined and motivated by budgetary considerations, it seems plausible that much of the variation in electricity tariff schedules is relatively exogenous to electricity demand by consumers in each consumer group. A challenge, however, is that the block pricing structure faced by many consumers means that shifts in electricity demand can influence the average price, introducing a potential for reverse causality.

In an attempt to address this issue, we employ an IV approach in our three-dimensional estimates. Specifically, we instrument the differenced log average electricity price with the differenced log average electricity price paid by consumers in the same consumer group and year, but *outside* the region. This exploits the fact that most regions implement the national electricity tariff schedule, so consumer groups in different regions are subject to similar underlying price shocks (although, as noted, these shocks are not identical due to variations in the composition of consumer groups, and due to the fact that Batam and Tarakan apply separate tariff schedules). The approach seeks to remove the effect of within-region reverse causality. It does not completely solve the identification challenge; consumer group-specific demand shocks could be correlated across regions, for example. The approach assumes that electricity price changes do not induce substantial electricity leakage across regions in the same year.

Negative estimates of $\hat{\beta}$ are expected, consistent with a downward-sloping demand curve. The effect is likely to be inelastic, as in many instances there are relatively few substitutes to grid-supplied electricity. Potential behavioural responses to higher electricity prices include reduced air-conditioning, use of more energy-efficient appliances, and substitution to other inputs (both energy and non-energy). One possibility is increased use of captive electricity generation (i.e. using a generator). While consumers are unlikely to substitute to diesel generators (given the high cost of producing electricity using diesel), some industrial enterprises may have substituted to captive generators that use natural gas (for example). The longer-run effect of price increases is expected to be larger than the one-year effect, as some responses take time.

Our panel may exhibit cross-sectional dependence resulting from consumer groups and/or regions being exposed to similar temporal shocks. A Breusch and Pagan (1980) Lagrange multiplier test indeed rejects the null of cross-sectional independence at the 1% level. Significance levels are similar, however, using the panel estimator of Driscoll and Kraay (1998), which produces standard errors non-parametrically adjusted for heteroskedasticity, autocorrelation, and potential correlation in error terms across panel units.

A final consideration is the potential for small consumer groups and regions to have undue influence on our results. We supplement our main estimates with results using weighted least squares (WLS), employing a weight equal to the square root of the number of consumers in each panel unit.

3.2 Data

We obtained data on electricity sales and sales revenue of PLN and its subsidiaries from both BPS (1997, 2001) and CEIC (2016). PLN and its subsidiaries account for nearly all sales of electricity in Indonesia.[4] Sales revenue includes both fixed charges and utilization tariffs, but excludes connection fees or transfers to PLN from the government. We calculate the average electricity price per kWh by dividing sales revenue by sales quantity. Our use of the average price is supported by evidence that individual consumers respond to the average rather than the marginal electricity price due to information and cognitive constraints (Shin, 1985), although this may not necessarily apply at the aggregate level. Electricity bills in Indonesia can also include some small additional charges such as stamp duty, local street light taxes, and value added tax, although most residences are exempt from the latter (PwC, 2016). These additional imposts are not included in our price measure. We refer to electricity sales quantity as "electricity use".

Data for other variables are from CEIC (2016), the World Bank (2016), PLN (multiple years), and NASA (2016). For consistency, the average electricity price, GDP, and diesel price are all in nominal terms. We avoid controlling for the consumer price index (CPI), which is directly influenced by electricity prices. The year fixed effects will remove the effect of national inflation in our two-dimensional estimates. In our three-dimensional estimates, region*year fixed effects will remove the effects of regional inflation. The consumer group*year fixed effects will remove the effects of consumer group-specific inflation.

Our two-dimensional dataset (consumer group, year) covers six consumer groups for 1992–2015. First differencing means the sample covers 1993–2015, or 138 observations (six consumer groups * 23 years). The "business" consumer group includes hotels, malls, transport, and other commercial operations. The "social services" group includes hospitals, schools, places of religious worship, and others. Our three-dimensional dataset (consumer group, region, year) covers 16 regions but only five consumer groups, as the government building and public street light groups are merged together in the available regional data. Electricity use summed across consumer groups or regions equals the national total, subject to minor rounding errors. We have aggregated provincial data for *Y* and *N* to closely match

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[4] Non-PLN sales equalled 0.7% of total electricity sales in 2015 (BPS, 2015b; PLN, 2015b).

the 16 regions. A full list of variable definitions and sources, together with the regional definitions, is in an Appendix. Our data and estimation commands will be available online.

It is important to note that while electricity use by prepaying customers is included in regional data, central collections of prepaid electricity revenue are not. The average electricity price is thus measured less accurately at the regional level. This is our reason for initially focusing on two-dimensional specifications by consumer group and year, using national data. Prepaid revenue reached 12% of PLN's revenue from electricity sales in 2015 (PLN, 2015b).

Fig. 4 plots differenced log electricity use against the differenced log average nominal electricity price, using national data. There is a negative association: years of larger average price increases tend to see slower growth in electricity consumption. 2013–2015 involved relatively large proportional increases in nominal electricity prices, although these were smaller than those seen in the years immediately after the AFC (a time of high inflation).

Fig. 4. Scatter plot of differenced log electricity consumption and price, 1993–2015
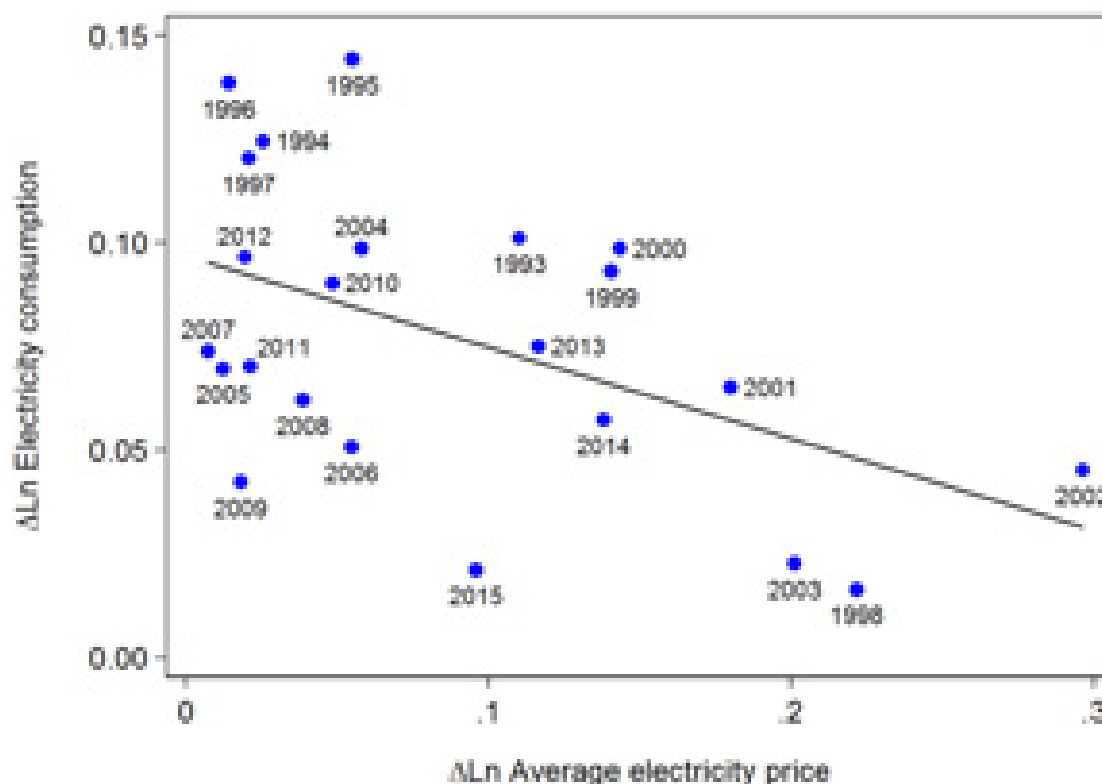
Notes: A fitted line is shown. The line has a slope of –0.22 and an R^2 of 0.24. Price is in nominal local currency terms. Sources: BPS (1997, 2001), CEIC (2016).

4. Results

4.1 Two-dimensional panel

Table 1 presents estimation results for our consumer group-year panel. Column 1 includes no controls, and suggests a same-year price elasticity of demand of –0.17, statistically different from zero at the 1% level. The remaining columns control for consumer group fixed effects. Column 2 includes a sub-set of the X controls; a similar same-year price elasticity of demand is obtained (–0.16). Column 3 adds the transmission lines and SAIDI variables. This reduces the sample due to non-availability of data for early years. We obtain a smaller price elasticity of demand (–0.12), significantly different from zero at the 5% level.

Table 1. Two-dimensional estimates

Dependent variable: ΔLn Electricity consumption$_{g,y}$

	(1)	(2)	(3)	(4)	(5)	(6)
ΔLn Electricity price$_{g,y}$	-0.17***	-0.16***	-0.12**	-0.14***	-0.18**	-0.17**
	(0.04)	(0.02)	(0.04)	(0.03)	(0.06)	(0.06)
ΔLn GDP per capita$_y$		-0.08	0.01	-0.03		
		(0.04)	(0.14)	(0.06)		
ΔLn Population$_y$		-0.64*	-0.64	-0.61*		
		(0.30)	(0.92)	(0.26)		
ΔLn Diesel price$_y$		-0.05***	-0.07***	-0.04**		
		(0.01)	(0.01)	(0.01)		
ΔTemperature$_y$		0.03	0.01	0.02		
		(0.02)	(0.02)	(0.02)		
Time trend$_y$		-0.003	-0.003	-0.002		
		(0.002)	(0.002)	(0.001)		
ΔLn Transmission lines$_y$			0.31			
			(0.25)			
ΔLn SAIDI$_y$			0.01			
			(0.01)			
ΔLn Electricity consumers$_{g,y}$				0.53**		
				(0.15)		
Consumer group fixed effects	-	Yes	Yes	Yes	Yes	Yes
Year fixed effects	-	-	-	-	Yes	Yes
Weighted least squares	-	-	-	-	-	Yes
R^2	0.10	0.27	0.29	0.50	0.48	0.62
Observations	138	138	90	138	138	138
Consumer groups	6	6	6	6	6	6
Years	1993–2015	1993–2015	2001–2015	1993–2015	1993–2015	1993–2015

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Robust standard errors clustered by consumer group are in parentheses. Coefficients on constants, consumer group fixed effects, and year fixed effects not shown. Column 3 is for a reduced sample due to the non-availability of data on transmission lines and SAIDI prior to 2000. Column 6 shows a weighted least squares estimate, with a weight equal to the square root of Electricity consumers$_{g,y}$.

Column 4 of Table 1 controls for the change in the log number of electricity consumers in each consumer group and year. The transmission lines and SAIDI variables are excluded. As mentioned, the same-year price elasticity of demand may be underestimated in this

specification because connecting to electricity is likely to be part of the demand response to prices, as well as representing expanded supply-side possibilities. The estimate is –0.14, different from zero at the 1% level. One percent more electricity consumers is on average associated with 0.5% more electricity use.

Column 5 of Table 1 includes year fixed effects. Variables that vary only by year are excluded to avoid perfect collinearity. We also exclude the log number of electricity consumers. The estimate is –0.18, again highly significant. Column 6 presents a WLS estimate, again similar.

Negative coefficients are obtained for the diesel price variable, suggesting diesel and electricity are complements at this aggregate level. This is perhaps because diesel is an input to electricity generation.[5] The cross-price elasticity is small, however (–0.05 in column 2). The transmission line, SAIDI, and log nominal GDP per capita variables enter insignificantly. In unreported results we find that changes in log *real* GDP per capita are significantly correlated with same-year changes in log national electricity use, with an elasticity of +0.6. Business (+1.0) and industry (+0.7) are the most GDP-sensitive in their electricity use, and public street lights (+0.3) the least.

Table 2 presents additional two-dimensional specifications. Column 1 estimates price elasticities of demand for each consumer group. The same-year point estimates are –0.20 for residences, –0.27 for business, –0.19 for industry, –0.16 for social services, –0.35 for government buildings, and –0.10 for public street lights. With the exception of public street lights, each differs from zero at the 10% level or higher. A small elasticity for public street lights makes sense; local administrators have a diluted incentive to economize on electricity, especially given that public street lights are largely funded by specific levies on consumer bills. The same-year price elasticities for each consumer group are presented in Fig. 5.

Column 2 of Table 2 presents an estimate for a sub-sample of the three large consumer groups. Year fixed effects are excluded. The point estimate remains similar (–0.19). Column 3 includes an interaction between the price term and a time trend. It provides no evidence that the same-year price elasticity of electricity demand has evolved over time. Column 4 allows the underlying secular trend in electricity use growth rates to differ by consumer group. A smaller elasticity is obtained (–0.13).

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[5] We note, however, that our diesel price variable uses the subsidized price for high speed diesel/gas oil, which is primarily transport fuel. This may display some variation vis-à-vis the price for diesel used in electricity generation.

Table 2. Consumer group heterogeneity and other estimates

Dependent variable: ΔLn Electricity consumption$_{g,y}$

	(1) Consumer group interactions	(2) Three large consumer groups only	(3) Time trend interaction	(4) Consumer group-specific time trends	(5) AFC and GFC dummies	(6) Only large price increases (>10%)	(7) Time-series of aggregate data
ΔLn Electricity price$_{g,y}$		-0.19** (0.02)	-0.16 (0.13)	-0.13* (0.06)	-0.18** (0.06)	-0.16** (0.04)	-0.19*** (0.06)
ΔLn Electricity price$_{g,y}$*Residences dummy$_g$	-0.20** (0.07)						
ΔLn Electricity price$_{g,y}$*Business dummy$_g$	-0.27** (0.10)						
ΔLn Electricity price$_{g,y}$*Industry dummy$_g$	-0.19* (0.08)						
ΔLn Electricity price$_{g,y}$*Social services dummy$_g$	-0.16* (0.06)						
ΔLn Electricity price$_{g,y}$*Government building dummy$_g$	-0.35*** (0.04)						
ΔLn Electricity price$_{g,y}$*Public street lights dummy$_g$	-0.10 (0.05)						
ΔLn Electricity price$_{g,y}$*Trend$_t$			0.00 (0.01)				
AFC dummy for industry$_{g,y}$					-0.07** (0.03)		
GFC dummy for industry$_{g,y}$					-0.11*** (0.02)		
Consumer group fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	-
Year fixed effects	Yes	-	Yes	Yes	Yes	Yes	-
R^2	0.51	0.25	0.48	0.65	0.51	0.48	0.70
Observations	138	69	138	138	138	138	23
Consumer groups	6	6	6	6	6	6	Aggregate

Years: 1993–2015

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Robust standard errors clustered by consumer group are in parentheses. Coefficients on constants, fixed effects, linear trends, and controls not shown. Column 2: The three large consumer groups are residences, industry, and business. Column 3: The time trend takes on the value of 0 in 1993, and increases by one in each subsequent year. Column 6: This variable equals 0 except in consumer group*years in which the average electricity price increased by > 10%. Column 7: One-dimensional estimates (i.e. g = total) with the following controls: ΔLn GDP per capita$_y$, ΔLn Population$_y$, ΔLn Diesel price$_y$, ΔTemperature$_y$, and Time trend$_y$.

Fig. 5. Estimates of the same-year price elasticity of electricity demand
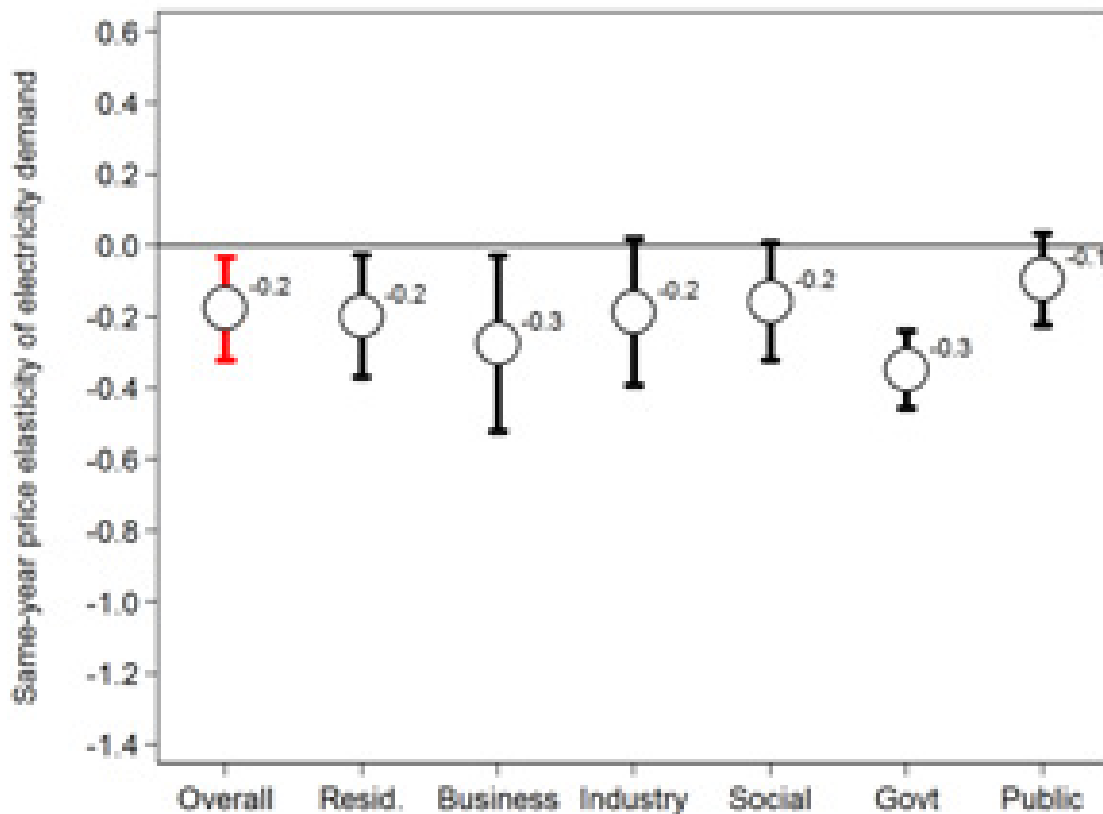
Notes: Resid. = residences. Social = social services. Govt = government buildings. Public = public street lights. These are the estimates from column 1 of Table 2.

Fig. 2 indicated that industry's electricity demand has been affected by some sector-specific shocks, for example when exports were hard hit during the AFC of 1998 and the global financial crisis (GFC) of 2009. In column 5 of Table 2 we include controls for the impact of these events on the industrial sector's electricity use. The coefficients suggest electricity use by industry was 7% lower than otherwise expected in 1998 and 11% lower than otherwise expected in 2009. Our estimate of the same-year price elasticity of electricity demand remains similar. A similar estimate is obtained if a full set of year dummies for industry is included (not shown).

As mentioned, it is problematic that changes in demand might influence the average electricity price, for example if consumers move to higher tariffs when their usage increases. This effect is likely to result in small increases in average electricity prices each year, as consumption quantities grow. As an alternative approach we used a differenced log electricity price term that only includes increases in electricity prices of 10% or more. This identifies the price elasticity using large price movements, which are mostly due to changes in official tariff schedules. We obtained a similar estimate (–0.16; column 6 of Table 2).

Column 7 of Table 2 uses one-dimensional time-series data for national electricity use, aggregated over the consumer groups and regions. The specification allows a check that the aggregate same-year price elasticity of demand is similar to the elasticity from a panel of consumer groups. A set of controls is included. We obtain a similar estimate of the same-year price elasticity of aggregate electricity demand (–0.19), differing from zero at the 1% level.

Table 3 includes distributed lags of the price variable. The multi-year price elasticity of demand is equal to the sum of the coefficients. We find a four-year elasticity of –0.4, different from zero at the 5% level. Interestingly, estimates of around –0.3 are obtained for the five-year, six-year, and seven-year elasticities, although for relatively small samples.

4.2 Using regional data
Table 4 presents our three-dimensional estimates. Column 1 uses no controls; we obtain a mean same-year price elasticity of demand of –0.30, significantly different from zero at the 1% level. The WLS estimate is –0.20 (see base of Table).

Column 2 of Table 4 adds consumer group*region fixed effects and a set of observed controls. The sample is reduced due to non-availability of data for early years. The same-year price elasticity of demand is reduced to –0.16. This reduction is due to the smaller sample rather than the effect of the controls. We find a negative and significant coefficient for the time trend, suggesting a slowing of electricity demand growth over time. Column 3 includes the log number of consumers. A positive and highly significant coefficient is again found for this variable. The same-year price elasticity of demand is similar.

Column 4 of Table 4 adds region*year fixed effects. A larger same-year price elasticity of demand is obtained (–0.39). Column 5 includes consumer group*year fixed effects. The elasticity increases to –0.49. Our only control to vary along all three dimensions is the log number of consumers. We include this in column 6, obtaining a similar result. WLS estimates are also similar (see base of table).

Column 7 of Table 4 presents an estimate with the full set of two-dimensional fixed effects but for a sample commencing in 2002. A same-year price elasticity of electricity demand of –0.20 is obtained. This suggests that the large estimates for our three-dimensional sample are due to a strong relationship in early years.

Table 3. Two-dimensional estimates with additional lags

Dependent variable: ΔLn Electricity consumption$_{g,y}$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ΔLn Electricity price$_{g,y}$	-0.18**	-0.14**	-0.16**	-0.16**	-0.14*	-0.14*	-0.15*
	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
ΔLn Electricity price$_{g,y-1}$		-0.14**	-0.11*	-0.12*	-0.12*	-0.12*	-0.13**
		(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
ΔLn Electricity price$_{g,y-2}$			-0.09**	-0.07	-0.04**	-0.05**	-0.05*
			(0.03)	(0.04)	(0.02)	(0.01)	(0.02)
ΔLn Electricity price$_{g,y-3}$				-0.05	-0.05	-0.06	-0.08
				(0.03)	(0.04)	(0.04)	(0.04)
ΔLn Electricity price$_{g,y-4}$					0.10	0.11	0.12
					(0.10)	(0.09)	(0.12)
ΔLn Electricity price$_{g,y-5}$						-0.05	-0.07*
						(0.04)	(0.03)
ΔLn Electricity price$_{g,y-6}$							0.02
							(0.09)
Consumer group fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
x-year price elasticity of demand	-0.18**	-0.28***	-0.37***	-0.41**	-0.26*	-0.31	-0.33
Same elasticity, for sample of 102 observations	-0.16**	-0.27**	-0.35**	-0.40**	-0.27**	-0.36**	-0.33
R^2	0.48	0.50	0.51	0.49	0.49	0.46	0.48
Observations	138	132	126	120	114	108	102
Consumer groups	6	6	6	6	6	6	6
Years	1993–2015	1994–2015	1995–2015	1996–2015	1997–2015	1998–2015	1999–2015

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Robust standard errors clustered by consumer group are in parentheses. Coefficients on fixed effects not shown. The *x*-year elasticity is the sum of the betas for all years in that column. Column 1 is identical to column 5 of Table 1.

Table 4. Three-dimensional estimates

Dependent variable: ΔLn Electricity consumption$_{g,r,y}$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Single-equation							IV
ΔLn Electricity price$_{g,r,y}$	-0.30***	-0.16***	-0.16***	-0.39***	-0.49***	-0.48***	-0.20**	-0.16***
	(0.10)	(0.04)	(0.04)	(0.12)	(0.15)	(0.15)	(0.08)	(0.05)
ΔLn GDP per capita$_{r,y}$		0.04	0.05					
		(0.03)	(0.04)					
ΔLn Population$_{r,y}$		-0.05	-0.04					
		(0.05)	(0.07)					
ΔLn Diesel price$_{y}$		-0.04	-0.04**					
		(0.03)	(0.02)					
ΔTemperature$_{r,y}$		0.01	0.01					
		(0.01)	(0.01)					
Time trend$_{y}$		-0.002*	-0.004***					
		(0.001)	(0.001)					
ΔLn Transmission lines$_{y}$		0.24**						
		(0.11)						
ΔLn SAIDI$_{y}$		0.00						
		(0.01)						
ΔLn Electricity consumers$_{g,r,y}$			0.63***			0.37***		
			(0.09)			(0.07)		
Consumer group*region fixed effects	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region*year fixed effects	-	-	-	Yes	Yes	Yes	Yes	Yes
Consumer group*year fixed effects	-	-	-	-	Yes	Yes	Yes	-
R^2	0.16	0.21	0.32	0.50	0.60	0.62	0.50	0.40
First stage:								
Coefficient on instrument	-	-	-	-	-	-	-	0.86***
F statistic on instrument	-	-	-	-	-	-	-	107.04
Weighted least squares estimate	-0.20***	-0.12***	-0.13***	-0.38***	-0.50***	-0.49***	-0.15**	-0.14***
Observations	1,820	1,200	1,200	1,820	1,820	1,820	1,120	1,820
Consumer groups	5	5	5	5	5	5	5	5
Regions	16	16	16	16	16	16	16	16
Years	1993–2015	2001–2015	2001–2015	1993–2015	1993–2015	1993–2015	2002–2015	1993–2015

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Robust standard errors clustered by consumer group*region are in parentheses. Coefficients on constants and fixed effects not shown. Weighted least squares estimates use a weight equal to the square root of Electricity consumers$_{g,r,y}$. Column 8: The explanatory variable is instrumented with ΔLn Electricity consumption$^{\text{Elsewhere}}_{g,r,y}$. The Stock-Yogo test statistic for 10% maximal IV size is 16.38.

Column 8 of Table 4 shows our IV estimate. We exclude the consumer group*year fixed effects given that our instrument utilizes consumer-group specific price shocks. We obtain an estimate of the same-year price elasticity of electricity demand of –0.16, significantly different from zero at the 1% level. Our instrument performs well in the first stage, easily passing the Stock and Yogo (2005) weak instrument test.

Table 5 presents estimates for a region*year two-dimensional panel. Column 1 suggests a same-year price elasticity of electricity demand of –0.14. Column 2 explores if this elasticity differs between Java and other areas; we find no strong evidence to conclude so. Column 3 tests if the elasticity has changed over time; the estimate does not provide strong evidence that this has been the case.

Table 5. Two-dimensional estimates by region and year

Dependent variable: ΔLn Electricity consumption$_{r,y}$

	(1)	(2)	(3)
ΔLn Electricity price$_{r,y}$	-0.14***	-0.14**	-0.17**
	(0.04)	(0.05)	(0.06)
ΔLn Electricity price$_{r,y}$*Java dummy$_r$		0.04	
		(0.05)	
ΔLn Electricity price$_{r,y}$*Time trend$_y$			0.01
			(0.01)
Region fixed effects	Yes	Yes	Yes
Control set	Yes	Yes	Yes
R^2	0.36	0.36	0.36

Observations: 240. Regions: 16. Years: 2001–2015.

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10%. Robust standard errors clustered by region are in parentheses. Regressions control for the same set of controls as column 2 of Table 4. Coefficients on controls, constants, and fixed effects not shown. The time trend takes on the value of 0 in 2001, and increases by one in each subsequent year. Year fixed effects are not included given that most variation in electricity prices is common across regions.

On the basis of our estimates, we conclude that the same-year price elasticity of aggregate electricity demand in Indonesia in recent years is –0.15 to –0.2 and that the four-year elasticity is around –0.4.

4.3 Impact of electricity subsidy reform on electricity consumption

What was the effect of Indonesia's 2013–2015 electricity price increases on electricity use? To answer this we use our estimates to simulate Indonesia's electricity use for a counterfactual of no tariff changes since 2013. The simulation allows a base rate of increase in average electricity prices for each consumer group of no more than 3.2% in any year, the average for the no-reform years 2004–2009.[6] We use the two-year price elasticity of demand

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[6] If a price increase of less than 3.2% was observed in any year during 2013–2015, this is used.

for each consumer group.[7] Our simulation suggests that the reforms of 2013–2015 had reduced annual electricity use by around 7% in 2015 relative to the counterfactual of no reform (see Fig. 6). This is the difference between our model's predicted electricity use and the prediction for the no-reform scenario. It is a large reduction, equal to 16 TWh per annum. The estimate suggests that around 7 TWh was from reduced electricity use by industry, 4 TWh from residences, and 4 TWh from business.

Fig. 6. Simulations of alternative electricity use paths
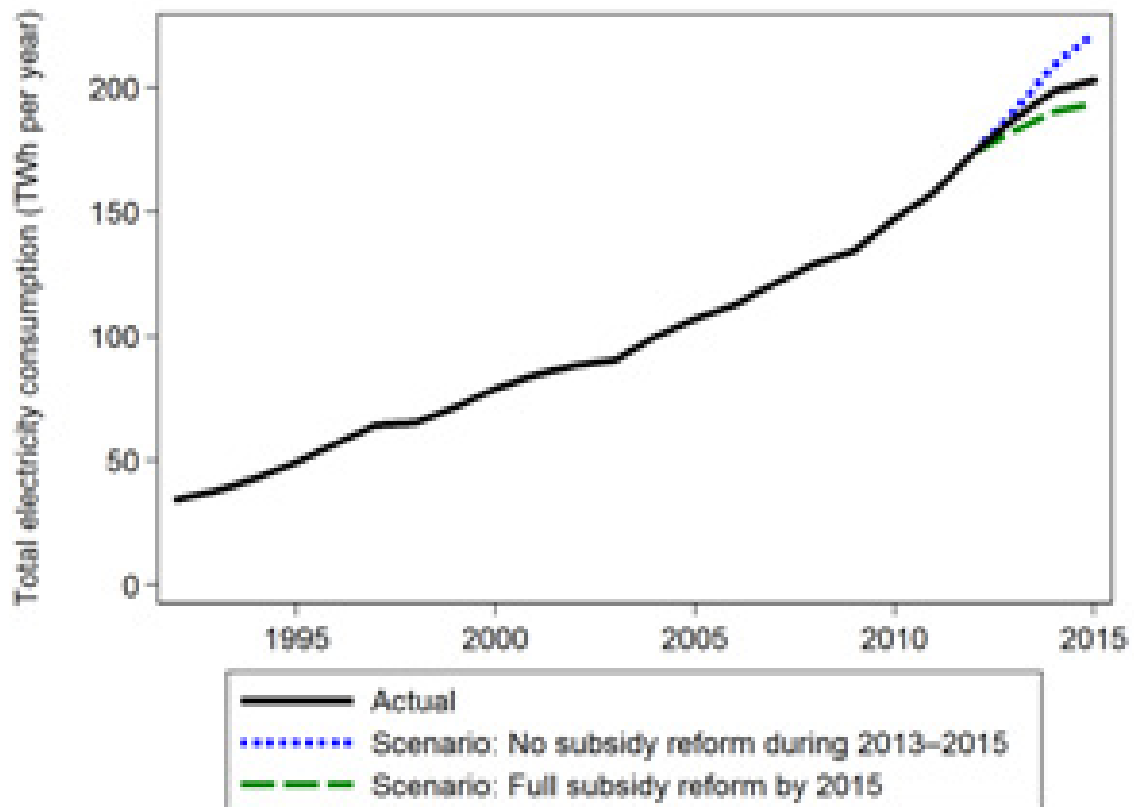
Notes: Scenarios are based on a two-dimensional consumer group-year panel regression with consumer group and year fixed effects, contemporaneous and first-lagged price terms, and interactions between consumer group dummies and the price terms. On-grid electricity only. Scenario predictions represent the demand-side effects of price changes, i.e. movements along the demand curves of each consumer group. Shifts in demand curves resulting from alternative uses of saved resources are not modeled. Implications of the reforms for electricity supply are also not modeled. The "no subsidy reform" scenario allows a base rate of up to 3.2% nominal growth in average electricity prices for each consumer group. The "full subsidy reform" scenario involves a linear progression to the average cost of production of 1,300.49 IDR per kWh in 2015 for consumer groups that have average prices lower than this. The scenarios are subject to confidence intervals.

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[7] We use a two-dimensional (consumer group, year) specification with consumer group and year dummies. Current and once-lagged price terms are included, each interacted with the consumer group dummies.

What would be the implications of a full phase-out of electricity subsidies? To answer this we simulate backdated linear increases in the average electricity prices paid by residences, businesses, industry, and social services over 2013–2015 so that prices reached the average cost of production of 1,300.49 IDR per kWh in 2015 reported by PLN (2015a). The simulation uses the observed average prices for government buildings and public street lights, as these exceeded 1,300.49 IDR per kWh. Second-order effects, for example via compensatory transfers to households or boosted investment in the grid, are not considered.

Results for the simulation are added to Fig. 6. We estimate that a full phase-out would have delivered additional electricity savings in the order of 6% of observed electricity use in 2015, or around 13 TWh per annum. Electricity use would have continued to increase, but along a more energy-efficient trajectory.

5. Conclusion

Indonesia has implemented major reductions to its electricity subsidies. In this study we estimated the aggregate price elasticity of electricity demand in Indonesia, and applied our elasticity estimates to quantify the demand-side effects of the reforms. Our estimates suggest that Indonesia's electricity demand is price inelastic, with a same-year elasticity of –0.15 to –0.2 and a larger elasticity when delayed responses are considered. This is quite consistent with estimates from other countries.

We calculate that subsidy reforms during 2013–2015 had induced demand-side savings in annual electricity use of around 7% relative to the counterfactual of no reform as of 2015. This is a sizeable reduction, consistent with the observed fact that, despite fast growth in the number of electricity connections, total electricity use grew at only 2.1% in 2015, the slowest rate this century. We estimate that the full removal of electricity subsidies would have induced additional electricity savings of around 6%. The long-run effects are likely larger.

As a result of its electricity subsidy reforms, Indonesia's electricity demand growth has grown at a slower rate than the government had anticipated. This has allowed PLN some breathing space in terms of requirements to scale up electricity generation capacity (Singgih and Sundaryani, 2017). The reforms have also freed up resources for priorities such as provision of other types of infrastructure. The reforms have likely reduced the risk of electricity outages, as the quantity of electricity demanded is now less likely to exceed available supply. Another probable effect is a reduction in emissions from the on-grid electricity sector; we estimate that reforms since 2013 averted around 13 million tonnes per

annum in annual carbon dioxide emissions from the on-grid electricity sector as of 2015.[8] Higher electricity prices have boosted the direct incentive for PLN to expand electricity access. The reforms have also boosted the prospects of renewables technologies, which now have better prospects of competing against on-grid electricity from predominantly fossil fuel sources. Economic theory suggests one should expect the move to more cost-reflective prices to result in sizeable reductions in deadweight losses.[9]

Indonesia has established itself as an exemplar in the speed and ambition of electricity subsidy reductions. While progress has not been completely smooth – planned increases in electricity tariffs in 2016 were postponed to 2017, for example – the overall reform process has been impressive. Most recently, electricity subsidies were withdrawn from households with 900 VA connections in 2017, with an exemption for poor households (Global Subsidies Initiative, 2017). It might at some point become feasible to remove electricity subsidies for even poor households, turning instead to other means of assistance. Indonesia has a system for targeting transfers to poor households (Bah et al., 2015) that could be used to this end.

It is important to be aware, however, that there is a sizeable threat of stalling and/or backsliding when it comes to Indonesia's electricity subsidy reforms. Huenteler et al. (2017) concluded that backsliding on cost-recovery initiatives for the electricity sector is indeed quite common in developing countries. Indonesia's budget allocation for 2018 involves an increase in spending on electricity subsidies, with no pathway of future steps to reduce subsidies (Wirayani and Sundaryani, 2017). Subsidies for consumption of liquefied petroleum gas (LPG) have also been growing, and subsidies for other fossil fuels such as diesel continue.

Indonesia considered a carbon tax in a 2009 Green Paper (Ministry of Finance, 2009), although the idea has yet to be pursued. One of the ways a carbon tax would help to reduce emissions is by incentivizing efficient electricity use. Our negative estimates of the price elasticity of electricity demand suggest that this incentivizing effect would indeed operate.

In the future there may be opportunities for Indonesia to have lower electricity prices without electricity subsidies. More competition within the wholesale level of the electricity sector is one way to potentially achieve this. New grid connections to neighbouring countries would

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[8] We use data from the IEA (2017b) and assume that the avoided electricity generation would have had the same emissions intensity as the average emissions intensity of electricity generation in 2014. We also assume that electricity supply would have been made available to meet additional demand in the no-reform counterfactual. Substitution to other energy sources may have partly offset these emissions reductions.

[9] See Davis (2014) for a method for calculating deadweight loss from energy subsidies.

offer electricity import opportunities. Ongoing reductions in the cost of solar, wind, and battery technologies also provide hope for a low-cost electricity future.

Our analysis does not measure the extent to which Indonesia's electricity subsidy reforms have encouraged use of efficient technologies; reduced use of air conditioners; substitution to off-grid electricity;[10] substitution to energy forms other than electricity; or electricity theft. Further work may be able to investigate these issues, as well as effects on other outcomes such as industrial production. Indonesia's cross-subsidy arrangements for electricity also warrant examination. There are many other prospective topics for economic and policy research on Indonesia's electricity sector, for example the design of appropriate mechanisms to foster rapid penetration of renewables.

Energy subsidy reform is a reform priority for not only Indonesia, but many other low- and middle-income countries (Newbery, 2017). Indonesia has shown that ambitious reforms can simultaneously deliver increased fiscal space and improved efficiency of resource use.

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[10] Data from the Ministry of Energy and Mineral Resources (2016) indicate that both (a) oil use by industry, and (b) total energy use by industry were lower in 2015 than 2013. There thus does not appear to have been large substitution to other energy sources.

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Appendix. Variable descriptions and list of regions

Electricity consumption: Electricity sales of PLN and its subsidiaries, in TWh. Sources: BPS (1997, 2001) for 1992–1999, CEIC (2016) for 2000–2015. Some corrections/adjustments were made. The data do not cover captive generation or non-PLN sales. Non-PLN sales are small.

Electricity price: Average electricity price, calculated by dividing sales revenue by total quantity of electricity sold by PLN and its subsidiaries. Sales revenue does not include connection fees, subsidy payments from the government, or taxes and charges. Unit: current IDR per kWh. Sources: BPS (1997, 2001) for 1992–1999, CEIC (2016) for 2000–2015. Some corrections/adjustments were made. Regional sales revenue does not include centralized prepayments.

GDP per capita: GDP in current IDR per person. Source for two-dimensional panel: World Bank (2016). Source for three-dimensional panel: CEIC (2016). Data for the three-dimensional panel vary by region. For regional data: we applied GDP growth rates using the 2008 System of National Accounts (SNA) to extend 1993 SNA GDP data to cover 2014 and 2015. Population data used are as below.

Population: Number of people. Source: CEIC (2016). Data for the three-dimensional panel vary by region.

Diesel price: Price of subsidized high speed diesel/gas oil, in current IDR per liter. This is the average of the regulated diesel price at the end of each month, weighted by the number of days in each month. This variable does not vary by region. Source: CEIC (2016).

Temperature: Area-averaged surface skin temperature in degrees Celsius, using data from the Modern Era-Retrospective Analysis for Research and Applications (MERRA) Model. Data are for a grid box of 0.5 x 0.667° spatial resolution centered in each region. We used the simple average of the monthly means. In the consumer group-year estimates, data for Jakarta are used. Source: NASA (2016).

Transmission lines: Length of transmission lines, in kilometer circuits (kmc). Source: PLN (2004, 2009, 2013, 2015a). Available for 2000–2015. Measured at the national level.

SAIDI: System average interruption duration index, calculated as $\frac{\Sigma\ UN}{M}$, where U is the annual power outage time (hours per year), N is the number of consumers interrupted, and M is the

total number of consumers. Source: PLN (2004, 2010, 2011a, 2011b, 2012, 2015a). Available for 2000–2015. Measured at the national level.

Electricity consumers: Number of electricity customers. Sources: BPS (1997, 2001) for 1992–1999, CEIC (2016) for 2000–2015. Some corrections/adjustments were made. The data do not cover non-PLN sales or captive generation.

Asian financial crisis (AFC) dummy for industry: Equal to 0 for all observations except industry in 1998 (=1).

Global financial crisis (GFC) dummy for industry: Equal to 0 for all observations except industry in 2009 (=1).

Years: Data are by calendar year.

Consumer groups: Residences, business, industry, social services, government buildings, and public street lights. In the three-dimensional data, government buildings and public street lights are merged into a group named "public sector".

Regions: Aceh; North Sumatera; West Sumatera and Riau; South Sumatra, Jambi, Bengkulu, Bangka Belitung, and Lampung; West Kalimantan; South, Central, North, and East Kalimantan, including Tarakan; North Sulawesi, Central Sulawesi, and Gorontalo; South, South East, and West Sulawesi; Maluku and North Maluku; Papua; Bali, West Nusa Tenggara, and East Nusa Tenggara; East Java; Central Java and Yogyakarta; West Java and Banten; Jakarta and Tangerang; PT PLN Batam. These are the 16 regions for which data are reported in early editions of BPS's *PLN Electricity Statistics*, based on PLN operational units. More disaggregated data are available for recent years, but we maintain the consistent grouping of 16 regions. Data for Batam are for 1996 onwards. This (alone) makes our three-dimensional panel unbalanced. Our three-dimensional estimates are similar if Batam and/or West Sumatera and Riau are excluded. We use aggregations of provincial GDP and population data that closely, but not perfectly, match the boundaries of the 16 regions.

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