Indoor Air Pollution and Infant Mortality: A New Approach

By IMELDA*

In most developing countries, cooking fuels emit indoor air pollutants that may lead to poor health. The World Health Organization claims that dirty cooking fuels are associated with approximately 4.3 million premature deaths each year (WHO 2016). The magnitude of this correlation varies widely across studies, and a causal link has not been clearly established.

Household behavior, among other factors, obscures health impacts. For example, the largest randomized control trial (RCT) found no effect from free use of new, cleaner cooking stoves, because households used them irregularly and inappropriately (Hanna, Duflo and Greenstone 2016). People may also take actions to avoid inhaling smoke or particulate matter, especially when the pollutants are obvious and cause discomfort. In cross-sectional studies, risks of alternative fuels and cooking stoves can be confounded by the use of multiple fuels, not all of which may be reported, plus many unobserved factors that may be associated with cooking fuel choices (Duflo, Greenstone and Hanna 2008).

In this paper, I explore the causal impact of a household fuel switching program on infant mortality. I use a quasi-experimental approach, leveraging what may be the largest kerosene to liquid petroleum gas (LPG) conversion program implemented in a developing country. The Indonesian government redirected kerosene subsidy budgets to LPG, a more efficient and cleaner fuel compared to kerosene[1]. This program, motivated mainly by a rising governmental cost of subsidizing kerosene, successfully reduced household use of kerosene by 83 percent in just 4 years.

I find that the program led to an increase in LPG use in place of kerosene and had no effect on the use of wood fuel. Four fewer infants died per 10,000 live births – a 1.1% reduction in infant mortality rate – than would have in the absence of the program. Globally, approximately one billion people still rely on kerosene and other polluting devices for cooking and lighting (Lam et al. 2012). I suggest that policy interventions that aim on reducing the use of kerosene and providing cleaner fuel alternatives (e.g. LPG) can be a way to reduce infant mortality rate.

I. Kerosene to LPG Program in Indonesia

The kerosene to LPG conversion program began in May 2007 due to the increasing cost of subsidizing kerosene. This program impacted 86 million people[2] over four years. The price of subsidized kerosene was \$ 0.41 per litre while the price of subsidized LPG was \$ 0.42 per kg[3]. Although the prices were similar, LPG burns more efficiently than kerosene as households would need approximately 0.4 kg of LPG for 1 liter of kerosene (Budya and Arofat 2011).

The Ministry of Energy and Mineral Resources selected the targeted districts in a given fiscal year mainly based on each district's level of kerosene usage and LPG infrastructure readiness. The program was aimed to convert 73 percent of households that have been using kerosene and have never used LPG. These households received initial free package (a LPG canister, an LPG stove, a hose and a regulator) and were allowed to refill the canister with the subsidized price. By 2008, the package had been distributed to 84 districts, mainly big cities in

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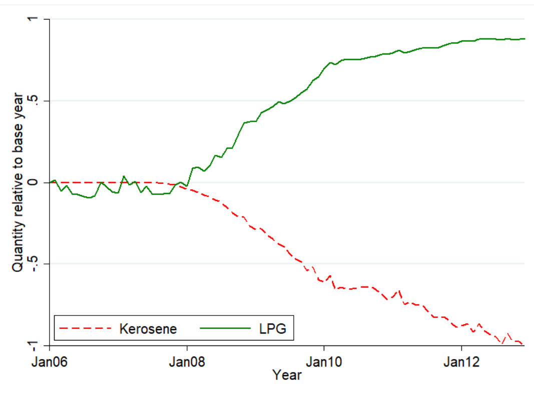
[1] It is widely known that LPG produces significantly less $PM_{2.5}$ than kerosene because of higher combustion efficiency (Peters et al. 1997, Smith, Rogers and Cowlin 2005, Lam et al. 2012, Barron and Torero 2017).

[2] Before the program, 40 percent of the population in the targeted regions used kerosene for cooking

[3] 1 IDR $\approx$ \$0.11 in 2007

Java and by 2011, the program has reached out to include 169 districts (out of 354). Figure 1 shows the gradual decrease in kerosene supply which is replaced by the increasing supply of LPG starting in January 2008.

Figure 1. : Monthly quantity of subsidized kerosene and LPG



Note: Supply of subsidized kerosene is relative to the 2006 quantity. Supply of subsidized LPG is relative to the 2012 quantity. Source: Pertamina.

II. Data

I use three rounds of the Indonesian Demographic and Health Surveys (IDHS) for the years 2002, 2007, and 2012. IDHS 2007 and 2012 include all provinces (33 regions and 354 districts) whereas IDHS 2002 excludes five regions: Nanggroe Aceh Darussalam, Maluku, North Maluku, and Papua due to unstable political situation. Census blocks in urban and rural areas were selected using multistage-stratified sampling for each province. The response rates for both household and individual interviews were 99 percent on average. Married women (15-49 years old) and/or household heads were asked about birth information within five years preceding the survey, maternal and household characteristics.

I define infant mortality as death within one year of birth. Ideally, births should be matched to the district, the month and year of the program implementation, but the data on the program implementation does not have this level of timing detail. To address this, I use two approaches: (1) I match births that occurred in the second half of the implementation year as the treatment group[4]; (2) I exclude the first year of the program implementation. As the results are insensitive to these approaches (see Appendix 3 column (1)), I later show the results from the first approach.

Following the literature, I use dummies for mother's and spouse's education, mother's age at child birth, young mothers (i.e. mothers younger than 18 years old), parents' smoking behavior, parents' visits to the health facility in the last 12 months, safe drinking water sources (i.e. water from protected wells, water pipe built inside the dwellings, bottled water or filtered water), availability of private toilets, electrification, ownership of fridge and TV, and for the firstborns as control variables.

III. Empirical Framework

I use a quasi-experimental approach, exploiting the sharp variation of fuel choices induced by the fuel conversion program to rule out the potential confounder due to the non-randomness of fuel choice. Links between indoor air pollution and infant mortality are more plausibly causal because infants are less likely to be mobile. They spend more time indoors. Moreover, they are not subjected to any accumulated effect from unknown lifetime exposure to indoor air pollution. I use difference-in-differences (DID) estimation strategy and compare within district and birth year average infant mortality rate between targeted and untargeted regions, following below equation:

$$(1)\quad y_{irt} = c + \alpha_r + \beta_t + \theta T_{rt} + \tau X_{irt} + \epsilon_{irt}$$

where y_{irt} be the outcome variable for infant i in region r at time t which takes the value of 1 if the infant died and 0 otherwise. α_r and β_t are district and year of birth fixed effects to capture permanent unobserved differences across districts and cohorts. X_{irt} is a set of covariates that capture birth, parental and household characteristics. I use ordinary least squares and cluster the standard errors at the district level.

T_{rt}, the key variable of interest, is a dummy

[4]I tried different monthly births cut-off ranges that occurred in February to October, and the results are insensitive to this cut off. The effect does look more precise starting with the third month (shown in Figure A)

indicating the program implementation in district r in year t. The identification strategy assumes that the timing of program implementation is uncorrelated with other changes after 2008, conditional on district fixed effects, cohort fixed effects and household level controls. This is a plausible assumption based on two tests: (1) I show similar pre-implementation trends in infant mortality existed in both targeted and untargeted districts in Figure 2 which reassure that the DID standard assumption is valid.; (2) I show that implementation timing has no association with trends in birth rates or household characteristics.

Figure 2. : Trend of Infant Mortality per 1,000 births

Note: This figure plots the mean of infant mortality rate in treated districts and untreated districts after 2008. X-axis indicates the beginning of the year of birth. Vertical dash line shows the beginning 2009 which is the start of the program implementation. Note that year-to-year trend in mortality rates is subjected to a considerable amount of noise.

My empirical analysis focuses on comparing changes in infant mortality rate within targeted and untargeted regions after 2008. I exclude 12,133 births in 2007-2008 because of following reasons. Firstly, the program had significant operational problems[5]. Moreover, the program also heavily targeted big cities – densely populated regions with a high level of kerosene consumption. Starting from 2009, the program was operated smoothly without major operational issues. Excluding these regions also excludes the potential 'unintended consequences' from those operational problems. Secondly, this selected sample excludes the period of financial crisis that happened in 2007-2008. A previous study on the impact of financial crisis in Indonesia indicates that the impact is not uniform across regions (Levinsohn, Berry and Friedman 2003). It is therefore useful to compare treatment and control groups that have similarity both in initial characteristics and trends as they are likely to be effected equally by the crisis.

This estimation is equivalent to the *intent-to-treat* (ITT) effect which provides a pragmatic benefit estimate of the policy rather than the actual measurement of fuel switching. The prevalence in ITT analysis is that it accounts for non-compliance and fuel stacking (e.g. when households used both kerosene and wood but reported wood as their primary cooking fuel).

[5]There was a strong resistance from the community (e.g. mass protests and negative public opinion in the media) and a simultaneous kerosene and LPG scarcity which then led to a significant rise in both kerosene and LPG prices

IV. Results

A. *Impacts on Fuel Choices*

Table 1 shows that the program, on average, led to a 10 percent decrease in the kerosene use, a 9 percent increase in the LPG use, and no effect on the wood use. This is unsurprising, given that wood users are not eligible for the program. It is possible that wood users may have illegally obtained subsidized LPG but the result in column (3) shows that this is not the case. Wood users likely do not have incentive to switch to LPG as wood fuel is the cheapest compared to all fuel alternatives and can be obtained with almost zero monetary cost.

Table 1—: Effect on fuel choices.

	LPG (1)	Kerosene (2)	Wood (3)
Treat	0.362	-0.344	-0.017
	(0.034)	(0.032)	(0.028)
Constant	0.104	0.372	0.511
	(0.074)	(0.065)	(0.037)
Mean	0.237	0.291	0.462
R-squared	0.329	0.225	0.283

Note: This table explores the program effect on the types of fuel used for cooking. All regressions include district fixed effects. Standard errors in parentheses are clustered at the district level. Sample size: 39,348.

B. *Impacts on Infant Mortality*

Table 2 shows that the program lead to a 1.1 percent decrease in infant mortality or 4 infants per 10,000 live births. The coefficient in the control variables are in line with the literature, such as young mothers and parents who smoke are associated with higher infant mortality rate. The estimates are consistent even after controlling for unobserved trends in household characteristics in column (3). The effect is slightly stronger with month-year of birth fixed effects in column (4). These findings demonstrate the consistency of the magnitude and the significance of the program effect across different set of controls. The improvement in indoor air pollution from using kerosene to LPG is smaller compare to the improvement if household using solid fuel (Smith, Rogers and Cowlin 2005) which might explain the small magnitude in the program effect.

Table 2—: Effect on infant mortality.

	Infant mortality			
	(1)	(2)	(3)	(4)
Treat	-0.011	-0.010	-0.011	-0.013
	(0.004)	(0.004)	(0.004)	(0.004)
Constant	0.001	0.020	0.216	0.167
	(0.028)	(0.031)	(0.219)	(0.218)
Observations	39,346	38,888	38,888	38,888
R-squared	0.044	0.048	0.053	0.058
Controls	No	Yes	Yes	Yes
ControlsXTime	No	No	Yes	Yes
Month Year FE	No	No	No	Yes

Note: This table explores the difference-in-differences effect of the program on infant mortality rate. Column 1 shows the base regression which includes dummies for birth order, recall period, and singleton and multiple birth. Column 2 adds the set of control variables. Column 3 adds the interaction between control variables and a dummy program. Column 4 adds month and year of births fixed effects. Mean of infant mortality is 36 per 1,000 live births. Standard errors in parentheses are clustered at the district level.

In addition to the parallel trend shown in Figure 2, I do further robustness checks. Table 3 shows that the estimates are robust to the exclusion of the first year of implementation (column 1) and placebo treatments (column 2).

V. Discussion and Conclusions

This study proposes a new way to estimate the impact of changes in indoor air quality induced by the cooking fuel intervention which potentially have two benefits. First, pollutants from burning cook fuel is believed to be the largest contributor of indoor air pollution. Second, the program is likely to be exogenous from household fuel choice, unlike person-specific particulate exposure which is potentially endogenous to the fuel choice. (Pitt, Rosenzweig and Hassan 2006) provides a simple model that shows that time allocation for cooking is endogenous to health and thus might correlate with the fuel choice.

Table 3—: Robustness Checks.

	Infant mortality	
	(1)	(2)
Treat	-0.011	
	(0.005)	
Placebo		-0.001
		(0.005)
Sample	Exclude 1^{st} year	2002, 2007
Observations	38,550	25,551

Note: This table shows the robustness checks based on different specifications. All regressions follow model (3) in Table 2 which include the base model with the set of covariates and its interaction with the dummy program. Column (1) excludes the first year of the program because the month when the program started in a specific district is unknown. Column (2) uses placebo treatment using the sample before the program. Standard errors (in parentheses) are clustered by district.

It provides a causal link between switching to cleaner fuel and infant mortality rate. It suggests that a reduction in the use of kerosene improves health which is consistent with the first RCT that finds a reduction in lower acute respiratory infection among young children due to reduction in kerosene use induced by households electrification (Barron and Torero 2017). However, this study needs further investigation to confirm if the reduction in indoor air pollution induced by the program is the main mechanism that explains the reduction in infant mortality. Ongoing research examines this mechanism and other potential outcomes that might also be influenced by the program.

A sustainable program in clean energy intervention will require a right combination of incentives and restrictions for households. Indonesia's kerosene to LPG program is a unique policy intervention in household fuel conversion. It combines price subsidy and quantity restriction in the intervention. The switching to LPG is 'involuntary' in nature because the subsidized kerosene is removed from the targeted regions after the LPG distribution. Perhaps it is unsurprising to find a very high take-up rates due to this reason. My findings support the importance of behavioral responses which obscure health effects in the earlier studies (Hanna, Duflo and Greenstone 2016).

By 2011, the program at least reduce 600 infant deaths annually[6]. In the developing world, one billion kerosene users switching to LPG can save about 7,000 infants per year. This study provides a rare and thus valuable evidence on the health effects from a clean energy intervention. Similar policy might be needed to encourage 41 percent of households worldwide to switch from dirty fuel to cleaner cooking fuel[7].

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[6] The number is based on 19.95 birth rate per 1,000 population from 86 million kerosene users in the targeted regions.

[7] As of 2010, an estimated 41 percent of households worldwide still relied on dirty fuel for cooking (Bonjour et al. 2013).

Online Appendix to
Indoor Air Pollution and Infant Mortality: Evidence from Indonesia

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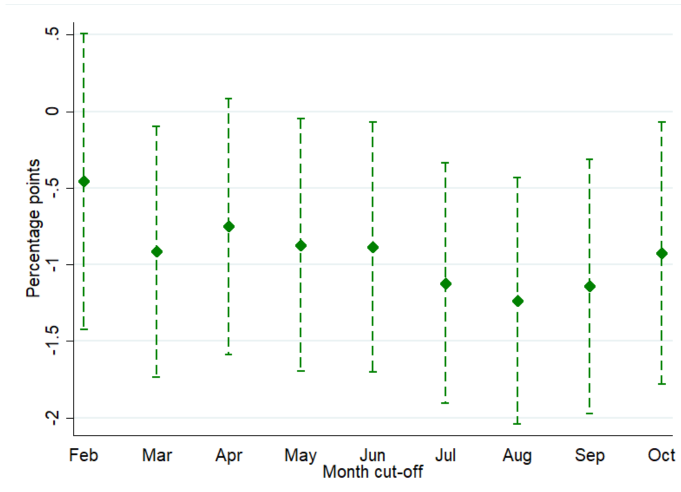
APPENDIX

Figure A1. : Robustness with the cut off month



Note: This figure plots each coefficient of the treatment effect from a separate regression using different monthly births cut-off indicated in y-axis. For example, for February cut-off, I match births occurred after February 2009 to districts that had the program implemented in 2009 as the treatment group.