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Fuelling the Engines of Liberation with Cleaner Cooking Fuel*

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Abstract: *Using the staggered roll-out of the Indonesian Conversion to Liquefied Petroleum Gas (LPG) Programme, we show that a subsidy for the labour- and time-saving cooking technology increased female labour force participation. The programme also increased household consumption expenditure and the decision-making power of women in the household, especially in financial matters. A back-of-the-envelope calculation suggests that the benefits of switching to LPG far outweighed the costs to the households. Based on previous research, we conjecture that intra-household externalities and gender differences in preferences drive the low rates of adoption of cost-effective technology. The programme's impact on the financial decision-making power of women suggests that subsidies which empower women, even if temporary, can encourage the adoption and sustained use of beneficial technology.*

Keywords: Household technology; Time-saving; Female labour; Decision-making

JEL Classification: D13; J22; O14; Q4

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1. Introduction

Women held back from participating in productive market activities is human capital wasted. It is now well established that the difference in rates of female labour force participation (FLFP) is an important explanation behind the persistent differences in gross domestic product (GDP) per capita across countries (Bloom et al., 2009). Despite this, females form a little more than a third of the formal labour force of the world, with their participation rates ranging from as low as 6% in Yemen to as high as 84% in Rwanda and Madagascar (World Bank, 2018). What explains these large differences in FLFP across countries?

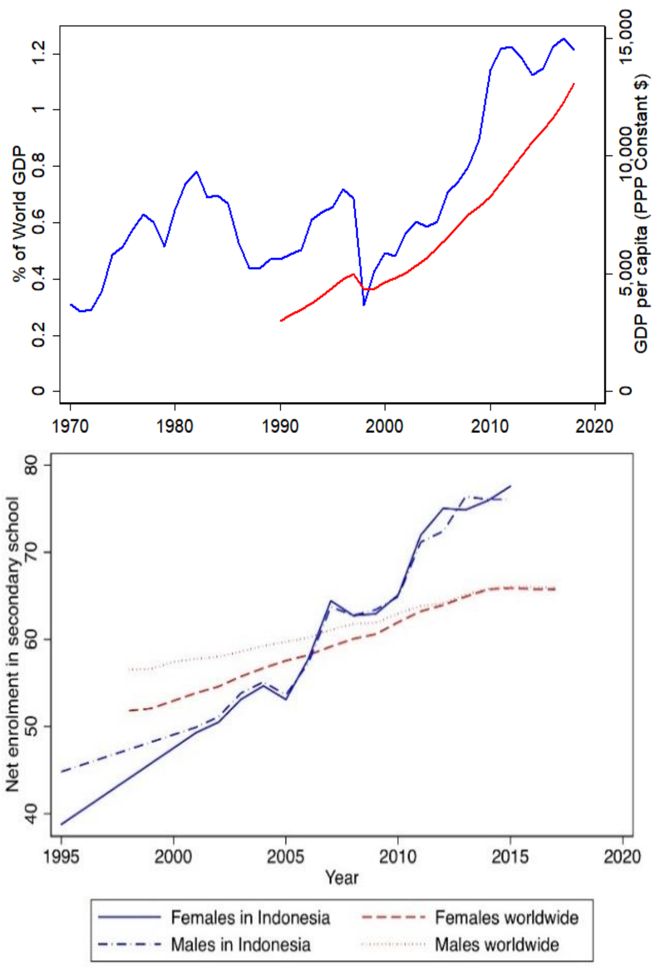
Previous research has suggested that several factors – including the desirability of the jobs available, medical and production technology, discrimination, availability of childcare, and cultural attitudes – affect FLFP.[1] While it is likely that a combination of factors is driving these differences, one potential explanation that has not received enough attention in the context of developing countries is that of 'engines of liberation' (Greenwood, Seshadri, and Yorukoglu, 2005). The emergence of cheap, time-saving household technology has often been credited with liberating women from the burden of household responsibilities and facilitating their integration into the labour force in developed countries (Cutler, Glaeser, and Shapiro, 2003; Goldin, 2006; Aguiar and Hurst, 2007; de V. Cavalcanti and Tavares, 2008; Coen-Pirani, León, and Lugauer, 2010). However, there is only limited evidence on the liberating effect of such technology in developing countries. While household responsibilities are still one of the biggest impediments to FLFP in developing countries (Schaner and Das, 2016), empirical verification is needed to assess whether women in labour-abundant developing countries who have been so liberated will seek and find employment easily.

Against this backdrop, we study the role of a subsidy for household cooking technology in determining FLFP in Indonesia. Like many other low- and middle-income countries, Indonesia has grown steadily over the last few decades. While

[1] See, amongst others, Goldin et al. (1994); Galor and Weil (1996); Costa (2000); Goldin and Katz (2002); Attanasio, Low, and Sánchez-Marcos (2008); Albanesi and Olivetti (2009); and Fernández (2013).

the welfare gains from this phase of rapid growth in Indonesia have been shared equally between males and females in domains such as education (Figure 1), the FLFP in Indonesia has remained below the world average.[2] An opportunity to examine the role of household cooking technology in determining FLFP presented itself when, in 2007, Indonesia implemented the national Conversion to Liquefied Petroleum Gas (LPG) Programme.

Figure 1: Trends in GDP and Education in Indonesia



GDP = gross domestic product, PPP = purchasing power parity.
Note: GDP per capita in constant United States dollar terms.
Source: Based on the World Bank (n.d.), National Accounts Data. https://data.worldbank.org/ (accessed 30 August 2019); and Organisation for Economic Co-operation and Development (n.d.), National Accounts data files. https://stats.oecd.org (accessed 30 August 2019).

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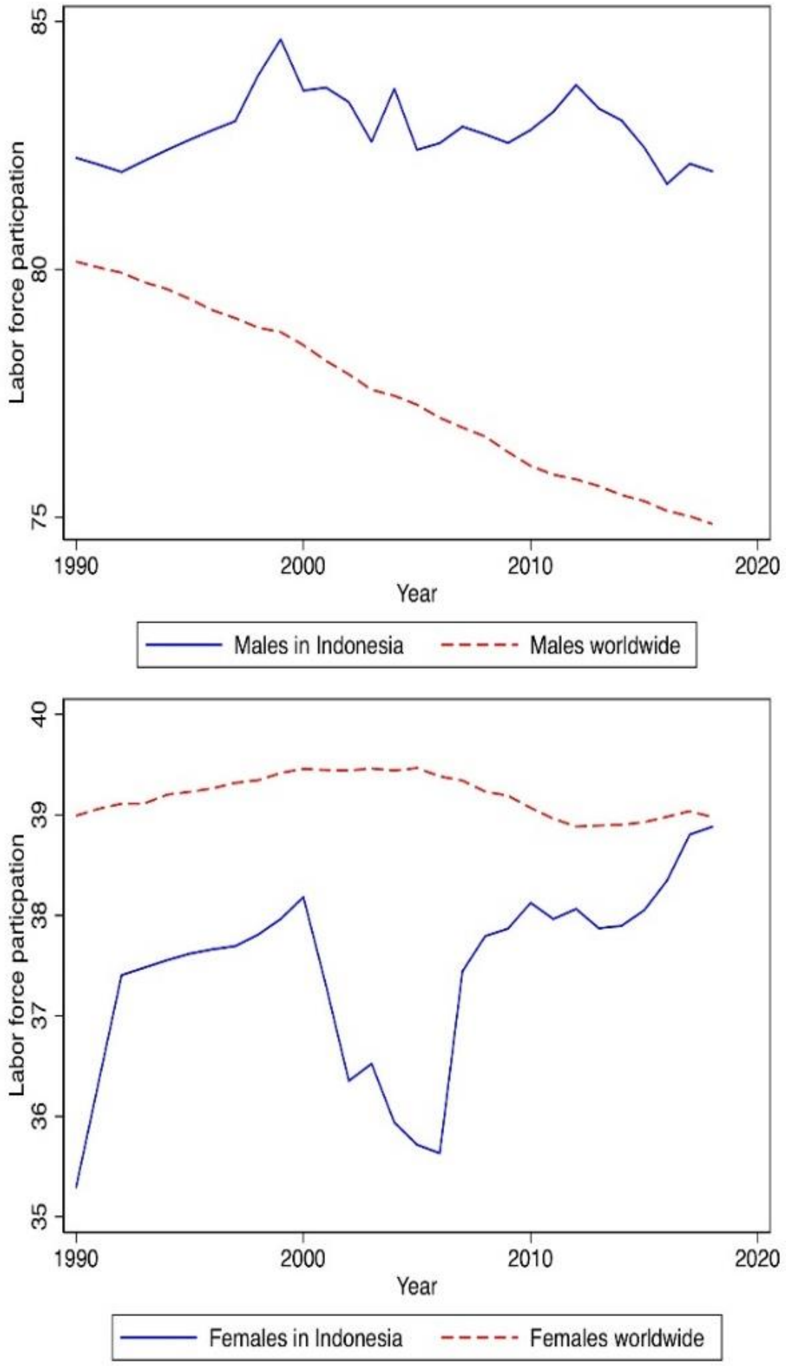
[2] In comparison, the labour force participation of Indonesian men has stayed well above the world average and has been relatively stable in the last three decades. See Figure 2.

Figure 2: Labor Force Participation in Indonesia and Worldwide



Source: Based on the World Bank (n.d.), National Accounts Data. https://data.worldbank.org/ (accessed 30 August 2019); and Organisation for Economic Co-operation and Development (n.d.), National Accounts data files. https://stats.oecd.org (accessed 30 August 2019).

The programme, also known as the ‘No-Kero’ or ‘Zero-Kero’ programme, subsidised the use of LPG. Studies from Indonesia have found that LPG is a labour- and time-saving cooking technology (Zhang et al. 2018; Thoday et al., 2018). Using the staggered roll-out of the programme, we show that a switch to LPG increased the labour force participation of exposed women.[3] We explore two possible mechanisms through which the switch to LPG might have affected the labour force participation of women – better health and time savings. Consistent with previous research on the topic, we do not find major effects on the health of the exposed women (Smith-Sivertsen et al., 2009; Hanna, Greenstone, and Duflo, 2016; Thoday et al., 2018). While we do not have information on the time use of the exposed women, building on information from related studies, we postulate that time saved due to the technology is an important pathway through which the switch to LPG might have affected the labour force participation of women.

A back-of-the-envelope calculation suggests that savings in household expenditure on fuel far outweighed the cost of the conversion incurred by the government. We conjecture that households fail to switch to LPG despite the unambiguous net gains because of intra-household externalities and gender differences in preferences – the benefits from switching to a cleaner fuel are greatest for the woman in the household but the monetary price is most often paid by the earning male (Miller and Mobarak, 2013; Pitt, Rosenzweig, and Hassan, 2006). We also show that the policy improves the decision-making power of women in the household, especially in financial matters. Given the role of intra-household externalities and gender differences in preferences, this has important implications for the sustained use of LPG even after the subsidy is withdrawn.

The paper makes three main contributions. It is the first paper to evaluate the impact of the No-Kero programme on the labour force participation and intra-household decision-making power of those exposed. In that, it adds to the small but growing microeconomic literature on the effects of physical infrastructure on labour market outcomes in developing countries (Dinkelman, 2011; Lipscomb, Mobarak, and Barham, 2013; Chakravorty, Pelli, and Marchan, 2014). Evaluations of the

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[3] Exposed women or households are those who resided in provinces that received the subsidy programme.

effects of physical infrastructure, which typically focus on health, education, and poverty, tend to overlook the employment and empowerment effects of household infrastructure. Our results show that the benefits of the policy went far beyond the saved subsidy expenditure, the main motivation behind the programme. Second, the findings are related to the limited literature on the effects of changing constraints on women's work in the process of economic development in developing countries (Dinkelman, 2011).[4] This is especially important for countries such as Indonesia, which does not fare too well on gender equality indices, where the working status of women is an important correlate of women's decision-making power within the household and attitudes towards domestic violence (Schaner and Das, 2016). Third, our findings also relate to the strand of literature that investigates the seemingly low rates of adoption of simple, relatively inexpensive, highly effective technologies in developing countries which have the potential to improve the quality of life through their impacts on health and productivity.[5] To the extent that intra-household externalities and gender differences in preferences drive the lack of adoption (Wickramasinghe, 2011; Miller and Mobarak, 2013; Goodwin et al., 2015; Tuntivate, 2015; Zhang and Adams, 2016; Durix, Carlsson Rex, and Mendizabal, 2016; Mohapatra and Simon, 2017), we show that such temporary subsidies can increase women's decision-making power through their liberating effect. This can encourage the widespread adoption and sustained use of such technology, even if the subsidy is later withdrawn.

While closest to Dinkelman (2011), Lipscomb, Mobarak, and Barham (2013), and Chakravorty, Pelli, and Marchan (2014), which document the positive employment and income effects of electrification, our study differs from evaluations of electrification in important ways. As shown in Lipscomb, Mobarak, and Barham (2013), electrification often boosts the demand for labour through

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[4] This is, as mentioned, in contrast to the large and compelling evidence from developed countries. See, in addition to the studies cited above, Goldin (1995); Mammen and Paxson (2000); Bailey and Collins (2011).

[5] See, for example, Foster and Rosenzweig (1995); Miguel and Kremer (2004); Bandiera and Rasul (2006); Duflo, Kremer, and Robinson (2008); Ashraf, Berry, and Shapiro (2010); Cohen and Dupas (2010); Conley and Udry (2010); and Foster and Rosenzweig (2010).

improvements in labour productivity.[6] In comparison, a switch to a faster household technology fuel primarily increases the supply of labour. Further, the demand shift due to electrification is often gender-neutral but the supply shift due to a faster household technology can benefit women more than men. An understanding of the distinct effects of different types of physical infrastructure on the supply and demand of labour is crucial for designing intelligent policies.

Another key difference is that studies examining the causal effects of electrification have, without exception, used supply-side interventions that cover most households in a large geographical area at a time. The absence of electricity, therefore, does not pose the interesting question of why households sometimes do not adopt simple welfare-enhancing technologies that are readily available. Following our findings, since electricity benefits all genders, intra-household bargaining might not play as important a role as it does for LPG adoption. In addition, while electrification covers large geographical areas at a time, the evaluation of the LPG programme allows us to better identify the characteristics of households on the margin.

2. Background

At the turn of this millennium, kerosene was the main fuel used by Indonesian households for their cooking requirements. In 2004, 48 million of the 52 million Indonesian households depended on kerosene, mostly for their daily cooking requirements and as lighting fuel (Budya and Arofat, 2011). The government had provided large subsidies on kerosene for decades and the subsidy payouts were turning out to be a huge burden on the state, sometimes as high as 18% of the state's total expenditures.[7] In its attempt to reduce the subsidy burden, in 2007, the

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[6] In addition to the direct effects on operations, electrification might also lead to lower information and transportation costs. The supply-side effect due to liberation, which may exist, could be small.

[7] The situation was worsened by the reduction in subsidies for industrial fuels (diesel, industrial diesel oil, and marine fuel oil) in early 2005, pricing them at international prices. The price disparity between the fuel prices for industries and households led to a substitution of kerosene for industrial fuels wherever possible and, as a result, an arbitrage opportunity. The subsequent smuggling caused large leakages in the subsidy, increasing the cost even further.

Indonesian government launched the Conversion to LPG programme to promote the use of LPG in Indonesian households.

LPG was the replacement choice for a variety of reasons. First, it was estimated that LPG would greatly reduce the subsidy cost per unit of end-use calorific value of energy delivered for cooking and subsidy per unit of fuel. Based on calculations by a team from the University of Trinity in Jakarta and the State Ministry of Women's Empowerment, which included laboratory experiments under various cooking conditions in Indonesia, it was found that 1 litre of kerosene was equivalent to 0.39 kilogrammes of LPG in terms of its end-use energy value (Budya and Arofat, 2011).[8] Based on the 2006 calculations alone, this would have saved the state $2.17 billion according to Budya and Arofat (2011). Second, LPG was a cleaner substitute with lower indoor pollution, which directly affected the health of the users, and lower levels of greenhouse-related pollutants than solid fuels.[9] Third, the infrastructure required to implement the transition to a cleaner fuel was more developed for LPG than for other alternatives such as electricity. Successful implementation of subsidised LPG programmes in the neighbouring countries of Malaysia and Thailand provided additional motivation.

Depending on the readiness of the LPG procurement, storage, and distributional infrastructure in the region, the programme was rolled out at different times in different regions. Urban regions often obtained the programme earlier (Budya and Arofat, 2011). By 2008, all of Jakarta, Bali, Yogyakarta, Banten, and parts of West, Central, and East Java had been covered. By 2009, all of Java and Bali, and parts of Lampung, South Sulawesi, East and West Kalimantan, South and North Sumatra, and Riau had received the programme. By 2011, the programme covered all of Aceh, North Sumatra, Riau, Jambi, Bengkulu, Lampung, Kalimantan (except central Kalimantan), and Sulawesi (except central and Southeast Sulawesi). By 2013, West Sumatra, West Nusa Tenggara, Bangka Belitung, and the remaining regions of Kalimantan and Sulawesi were covered. Some regions, such as East Nusa Tenggara, Malaku, North Malaku, and Irani Jaya were not covered by the

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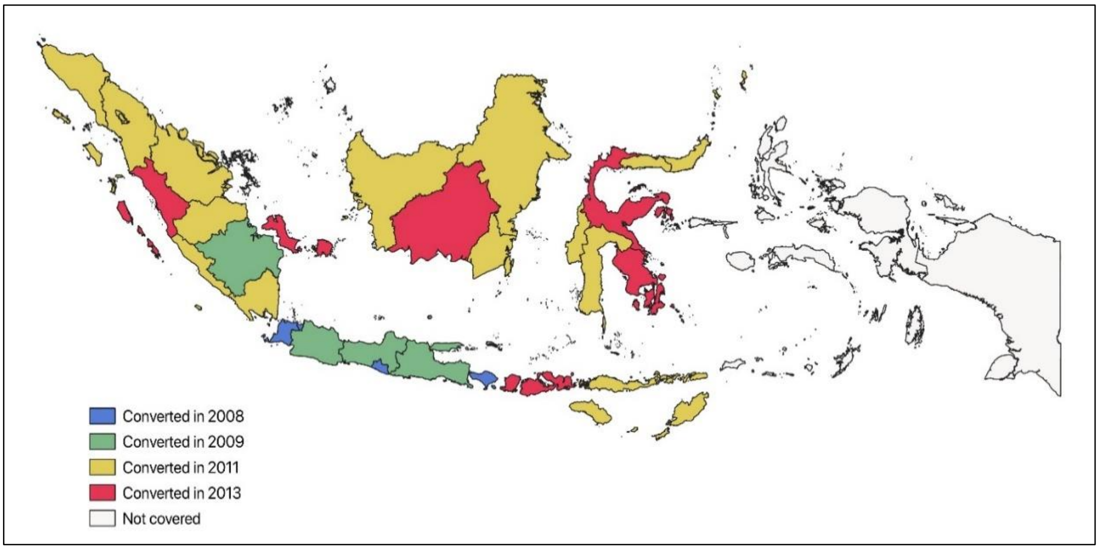
[8] This does not take into account the possible misuse of kerosene for industrial purposes, which would further tilt the scale in favour of LPG. See Budya and Arofat (2011) for a detailed calculation, accounting for such leakages.

[9] See Lam et al. (2012) and WHO (2014) for a review.

programme. As is clear, there was a substantial level of variation in the roll-out dates across provinces. Figure 3 depicts the variation in the roll-out of the programme.

Figure 3 Staggered Roll-Out of the LPG Subsidy Program Across Provinces



LPG = liquefied petroleum gas.
Notes: In some cases, the program was rolled out in different areas within a province in two consecutive years. However, we do not have information on roll-out at a finer level. For this reason, we define a province to have received the program only once all areas within the province were covered.
Source: Recreated based on Budya and Arofat (2011).

Under the programme, all eligible citizens were to receive a free 'initial pack' comprising a 3-kilogramme LPG cylinder with the gas, a one-burner stove, a hose, and a regulator; and could buy LPG at a subsidised rate thereafter. A few trial runs were conducted before the launch of the programme to gauge people's perception and acceptance of LPG as cooking fuel. The first test was carried out in Cempaka Baru Village, Kemayoran District, Central Jakarta, on 1 August 2006. Some 500 families were given the 'initial pack', and their responses and behaviours of the users were noted through surveys and observational methods. A second test was carried out with 18,800 households in Kemayoran District, Central Jakarta, and 6,700 families in Karawaci District, Tangerang, Banten in December 2006. This test was not accompanied by a survey, and evaluations were based on observations of people's reactions. The general picture from these market tests was that households were willing to switch to LPG under the subsidy (see Budya and Arofat (2011) for details). A third test was carried out in February 2007 when the Ministry of State-Owned Enterprises, under the State-Owned Enterprises Care programme to help flood victims in Jakarta, distributed 10,000 LPG cylinders in Kampung Makassar, East Jakarta. Here, too, the results were in favour of scaling up the programme.

The programme had a significant impact on the use of LPG as cooking fuel in Indonesia (Andadari, Mulder, and Rietveld, 2014). The share of LPG in household consumption expenditure increased from 1.9% in 2005 to 13.5% in 2013, while the share of kerosene dropped considerably from 18% in 2005 to 2% in 2013 (Toft, Beaton, and Lontoh, 2016). Many switched from solid fuels to LPG. Besides the savings in subsidy costs for the government, switching from kerosene or solid fuels to LPG might have had implications on community-level pollution and the depletion of natural resources such as forests; on food habits, budget allocations, resource distribution, and bargaining within the household; and on health, education, time use, and the labour force participation of individuals from the exposed household. A cost–benefit analysis in terms of subsidy cost savings alone is likely to understate the net benefits of the programme. However, there have hardly been any systematic evaluations of the impact on the programme, especially on factors affecting the health and economic well-being of those covered by the programme.[10]

For example, the adoption of modern household technology can have significant impacts on the labour force participation of household members. Multiple studies from the Organisation for Economic Co-operation and Development (OECD) countries document the causal effect of modern household technology, such as piped water, washing machines, refrigerators, and other durable consumer goods, on FLFP (Greenwood, Seshadri, and Yorukoglu, 2005; Goldin, 2006; Aguiar and Hurst, 2007; de V. Cavalcanti and Tavares, 2008; Coen-Pirani, León, and Lugauer, 2010). A related strand of literature examines the impact of access to electricity on the labour force participation of women in developing

[10] Andadari, Mulder, and Rietveld (2014) looked at the impact of the programme on energy poverty. They found that the programme led to increased stacking of fuels – increasing the consumption of both electricity and traditional biomass. It failed to reduce the overall number of energy-poor people although it was somewhat effective at reducing extreme energy poverty. Permadi, Sofyan, and Oanh (2017) found that the programme led to significant reductions in emissions of greenhouse gases and air pollutants.

countries. While access to electricity can affect both the demand and supply sides of local economies, it is, in many respects, similar to the adoption of modern household technology. Dinkelman (2011) found that the increase in rural South African households' access to electricity raised female employment by releasing women from home production and enabling microenterprises. Matly and France (2003) found that women in Indonesian and Sri Lankan households with access to electricity were more likely to do paid activities at home, such as processing clove nuts, wrapping local cigarettes, making joysticks, or weaving. Ramani and Heijndermans (2003) and Utomo (2015) found similar results, with the latter conjecturing that the increased FLFP was due to time savings.[11] It is, therefore, of interest to examine empirically if the LPG subsidy programme affected FLFP.

According to these studies, one of the most important pathways through which modern technology liberates women is by saving them time in household chores. It is likely that switching to LPG for their cooking requirements has similar time-saving effects. Igniting a solid-fuel or a kerosene stove to full capacity is substantially more work than switching on the LPG stove by turning a knob. Kerosene stoves can be categorised into two broad types depending on how the fuel is burned. Wick stoves rely on the capillary transfer of kerosene. As a result, one needs to wait after turning on the fuel for the wick to soak in kerosene all the way up to the top. The more common type, vapour-jet nozzle pressure stoves, are more fuel-efficient and faster but require manual pumping to aerosolise the fuel to get the stove started. Similarly, solid fuels require women to collect fuel and prepare it for use.[12] Moreover, multiple burners connected to the same LPG stove are quite common, but uncommon when cooking with solid fuels or kerosene.[13] While multiple burners do not reduce the time taken to cook a specific food item, this parallel processing reduces the overall time required for cooking. Since the cooking

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[11] See also Otte (2009).

[12] Aristanti (1997) found that women on the Indonesian island of Lombok spend 4 hours each week collecting deadwood or agricultural residue to be used as fuel. Pachauri and Rao (2013) found that women in India spend on average 3–4 hours per week collecting fuel for cooking, compared with 1–2 hours for men. In rural India, Khandker et al. (2014) reported similar figures: 10–12 hours for women and 5–6 hours for men.

[13] This could be because turning out another kerosene or solid fuel burner requires the same elaborate process described above.

activities in most developing countries are predominantly carried out women, the benefits of a switch to LPG, especially in terms of time saved, are likely to be higher for women (Pitt, Rosenzweig, and Hassan, 2006; Miller and Mobarak, 2013; Khandker et al., 2014).

In the 2016 study of the Indonesian domestic biogas programme of 2009, Gurung and Setyowati (2016) found that women save well over 1 hour per day when they switch to domestic biogas for their cooking needs. They also found that most of the saved time is spent on productive activities. Similarly, an in-depth survey of cooking fuel consumption and cooking habits in peri-urban households outside Yogyakarta City in central Java by the World Bank found that cooking with LPG was significantly faster than other methods (Zhang et al., 2018). When examining the preference for fuels and cooking stoves, the survey found that households preferred technologies that saved time. Studies evaluating other similar household technologies also found considerable time savings.[14] If women use the saved time productively in market activities, we might also expect a change in their decision-making power in financial matters and in household expenditure patterns (Attanasio and Lechene, 2002; Antman, 2014; Majlesi, 2016; Breuer and Asiedu, 2017). The switch to LPG can also affect FLFP through its direct effect on the health of the women in charge of cooking. However, the evidence on the health benefits of LPG vis-à-vis kerosene is mixed at best (Lam et al., 2012). We explicitly test if the programme had any health benefits.

3. Data and Identification

For our main analysis, we use the information from the 2000 and 2010 waves of the Indonesian Population Census (IPC) and the 1995 and 2005 waves of the Intercensal Population Survey of Indonesia (SUPAS). The censuses interviewed the entire population of Indonesia – Indonesian and foreign – residing in the territorial

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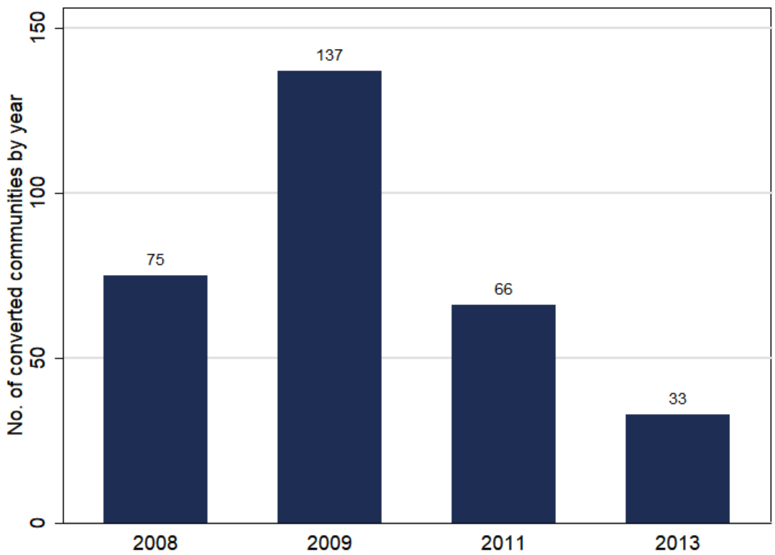
[14] Rosen and Vincent (1999) found that women in Zanzibar saved around 3 hours a day when electrified water pumping replaced the traditional methods of water collection. Similarly, replacing traditional hand milling with a diesel-driven mill saved households in Mali 30 minutes per day processing grains (Clancy et al., 2012).

area of Indonesia, regardless of residence status, including the homeless, refugees, ship crews, and people in inaccessible areas. Diplomats and their families residing in Indonesia were excluded. These censuses collected information on a wide range of variables, including the district and province of current residence and the primary fuel used by the responding households, as well as the educational attainment, employment status, age, and gender of the individual respondents.

Using information from these censuses, we first examine the impact of the programme on the households' primary fuel of choice and the employment status of individual respondents. While the large sample size of these censuses allows us to estimate the impact of the programme on these variables with great precision, they lack additional details about the households and the individual respondents – preventing further analysis of the programme. To get around this problem, we then use information from the third (2000), fourth (2007), and fifth waves (2014) of the Indonesian Family Life Survey (IFLS). The IFLS is an ongoing longitudinal household survey representative of about 83% of the Indonesian population living in 13 of the country's 27 provinces (Strauss, Witoelar, and Sikoki, 2016). The first wave was administered in 1993 to more than 22,000 individuals living in 7,224 households. The follow-up waves in 1997, 2000, 2007, and 2014 sought to follow the original respondents and their offspring in the same or split-off households. In the IFLS 5, 50,148 individuals living in 16,204 households were interviewed. The survey is remarkable for its low levels of attrition, with the re-contact rate of original IFLS 1 dynasties (any part of the original IFLS 1 household) in the IFLS 5 as high as 92%. We make use of waves 3, 4, and 5 of the survey for our analysis. The survey contains information on a wide variety of topics at the individual, household, and community level. At the individual level, we make use of information on the health, education, employment, subjective well-being, etc., of respondents. At the household level, we utilise the information on the main cooking fuel of the household and whether the household's kitchen is inside the house. Here, we first show that the impact of the programme on LPG usage, education, and employment is robust across the two data sets. Then, we examine the impact of the programme on a wide range of outcomes, including health and decision-making within the household.

The information on the variation in programme roll-out across regions is obtained from Budya and Arofat (2011) and Thoday et al. (2018). As described above, in certain cases only part of a province was covered in a given year. The rest of the province was covered in the following years. Within a province, the programme roll-out timing did not follow strict administrative boundaries. Therefore, we define a province to have received the programme only if the entire province was covered. This induces some degree of measurement error that will bias the estimates downwards.[15] Figure 4 depicts the variation in the roll-out of the programme across the communities in the IFLS data and Tables 1 and 2 reports the summary statistics for the two data sets we use.

Figure 3: Difference in LPG Program Roll-Out Across IFLS Communities



IFLS = Indonesian Family Life Survey, LPG = liquefied petroleum gas.
Note: In some cases, the program was rolled out in different areas within a province in two consecutive years. However, we do not have information on roll-out at a finer level. For this reason, we define all communities within a province to have received the program only once all areas within the province were covered.
Source: RAND Corporation (n.d.), 'The Indonesia Family Life Survey'. https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

[15] To see this, note that the measurement error arises from the possibility of categorising exposed regions in the province not completely covered by the programme as unexposed (control) regions. Since exposed regions are expected to have a higher rate of LPG adoption or FLFP, mis-categorisation of the sort will increase the average level of LPG adoption or FLFP in control regions. Therefore, the estimate of the treatment effect, the conditional mean difference between the control and exposed group, will be smaller.

4. Empirical Specification

By the time of the 2010 census, some provinces in Indonesia had received the LPG programme while others had not. If the programme had been randomly assigned to the provinces, we could have attributed the differences in the outcome variables of interest across the provinces that had received the programme (henceforth, exposed provinces) and the provinces that had not (henceforth, control provinces) as the causal impact of the programme. However, as we point out in section 2, the roll-out of the programme was not random. Regions where the LPG procurement, storage, and distribution infrastructure was ready, received the programme. It is likely that the exposed provinces were different from the control provinces, along with a number of dimensions including our outcome variables of interest or the factors that drive these outcomes. To account for this, we use a difference-in-differences strategy. We compare the changes in our outcome variables of interest from 2005 to 2010 for provinces that had received the programme by 2010 with provinces that had not received the programme by 2010. Accounting for pre-existing differences across the provinces, we expect that households in provinces that had received the programme by 2010 must have increased their LPG usage more than those in control provinces.

The identifying assumption here is that in the absence of the programme, the change in these outcome variables of interest should have been the same in the exposed and control provinces. Said differently, the trend in a variable of interest over time in the exposed provinces in the absence of the programme is assumed to have been the same as the trend in the variable in the control provinces (henceforth, the parallel trends assumption). We first provide support in favour of the parallel trend assumption by showing that the variables of interest trended parallel in exposed and control provinces before 2005. Then, we estimate the following equation:

$$Y_{idpt} = \alpha + \beta \times Post_t \times Treat_p + \tau_t + \delta_{dp} + \varepsilon_{idpt} \qquad (1)$$

where Y_{idpt} is the outcome variable of interest for household or individual i living in district (*kabupaten*) d of province p in year t. At the household level, the outcomes of interest are whether or not the household used LPG as the primary cooking fuel. At the individual level, we are most interested in the impact of the programme on the labour force participation of those exposed to the programme, especially that of females. $Post_t$ denotes the pre- and post-roll-out period. It takes the value of 0 for 2005 and 1 for 2010. $Treat_p$ is an indicator variable that takes the value of 1 for all districts in all the provinces that had received the programme by 2010, and 0 otherwise. τ_t controls for time-varying factors that were common to exposed and control provinces and could have affected the outcome of interest. δ_{dp} controls for time-invariant differences across districts that could have affected the outcome.[16] To maintain consistency with the specifications that follow, we cluster the standard errors at the level of the district. Clustering them at the level of the province does not affect the statistical significance of the results.

However, provinces in Indonesia are considerably different – not only in their population (ranging from a few hundred thousand to well over 40 million) and their geographical area (from a little over 650 square kilometres to over 300,000 square kilometres) but also in their distance from the government's seat in Jakarta or other large urban commercial centres in the country. As a result, it is possible that even though the time trends in variables of interest for the exposed and control provinces are parallel on average, there are time-varying unobservable differences across provinces that might bias our results. For example, consider a scenario where some provincial administrations in charge of the LPG programme bundled the LPG programme with other programmes that affected the outcomes of interest while others did not. If so, if we estimate the model in (1), we will attribute any effect of these other programmes on the outcome to the LPG programme.

To get around this problem, we use a modified version of the shift-share instrument – we interact $Post_t \times Treat_p$ with the proportion of households in district d of province p that used kerosene as their primary cooking fuel in 2005.[17]

[16] Replacing district fixed effects with province fixed effects does not change our results.

[17] The shift-share instrument, often referred to as the Bartik instrument (Bartik, 1991), is used extensively in migration literature. Some early applications of the instrument include Altonji and Card (1989) and Card (2001; 2009). It leverages the observation that national policy will have a differential impact across different regions of the country, depending on the size of the population in each region affected by the policy.

The proportion of households in different districts within the provinces in Indonesia that used kerosene as their primary cooking fuel was vastly different. For the 258 districts included in the IPC and SUPAS, it ranges from as low as 0.03% to as high as 94.01% in 2005. In the IFLS survey, out of the 311 communities, none of the households in nine communities and all of the households in three communities used kerosene in 2000. The LPG programme was a national-level policy intervention and, therefore, the change in outcomes due to the programme should not be correlated with variation in kerosene usage within the province.[18] Therefore, while the timing and nature of the programme could have differed across provinces (shift), it is unlikely that it was associated with the differences across districts within a province, and the districts with a higher proportion of kerosene users before the programme within a province would have benefited more from the programme (share).[19]

There are two reasons why districts with a higher incidence of kerosene usage stood to benefit more from the programme. First, the LPG subsidy was rolled out to replace the kerosene subsidy. As a result, there was a high correlation between the phase-in of the LPG subsidy and the phase-out of the kerosene subsidy. This meant that while the cost of LPG decreased for all households in the regions that received the LPG subsidy, the relative price of kerosene went up even more for households that used kerosene before. Second, before the LPG programme, kerosene was a highly subsidised fuel. Households that chose not to use kerosene, even with the high subsidy, must have had a relatively inelastic demand for the fuel they used instead.[20] It is likely that a reduction in LPG prices might have been equally unsuccessful in getting these households to switch from their fuel of choice. Therefore, one can think of the variation in pre-programme kerosene usage across

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[18] 'National specification of targeted localities for conversion would be done centrally under control of the conversion team established by Pertamina' (Budya and Arofat, 2011: 7579).

[19] Our strategy is similar to Bleakley (2007) who combined the introduction of the hookworm eradication campaign in the southern United States in the 1910s with the variations in the hookworm infection rates before the campaign across regions to identify the impacts of hookworm eradication on later life outcomes. The author points out that different areas of the United States had distinct incidences of the hookworm disease and, therefore, stood to gain differentially from the campaign. The innovations in the treatment of hookworm were not related to or in anticipation of the future growth prospects of the affected areas.

[20] Firewood was the second most important primary fuel of choice before the programme.

districts as a variation in the magnitude of the subsidy or the extent of its coverage. We estimate the following specification:

$$Y_{idpt} = \alpha + \beta_1 \times Post_t \times Treat_p \times Kero_{dp,2005} + \beta_2 \times Post_t \times Treat_p + \tau_t \times Kero_{dp,2005} + \gamma_{tp} + \delta_{dp} + \varepsilon_{idpt} \qquad (2)$$

where the terms common with (1) are defined as before. $Kero_{dp,2005}$ is the percentage of households in district d of province p that used kerosene as their primary cooking fuel in 2005. β_2 captures the impact of the programme in districts where no one used kerosene as the primary cooking fuel in 2005. β_1 measures the increase in the impact of the programme with an increase in the pre-programme usage rate of kerosene. Following Acemoglu, Autor, and Lyle (2004), Hoynes and Schanzenbach (2009), and Hoynes, Schanzenbach, and Almond (2016), we also include interactions of the year fixed effects with the pre-programme proportion of kerosene users in the districts to control for possible differences in trends across districts with different levels of kerosene users. In addition, we include province-year fixed effects γ_{tp} to account for time-varying differences across provinces and δ_{dp} to account for time-invariant differences across districts. Even if some provinces rolled out the programme in combination with other programmes, the province-year fixed effects will control for such differences. Since there is no variation in $Treat_p$, $Kero_{dp,2005}$, and $Treat_p \times Kero_{dp,2005}$ within a district, their effects are absorbed in the district fixed effect δ_{dp}. The effects of $Post_t$ and $Post_t \times Kero_{dp,2005}$ are absorbed in the $\tau_t \times Kero_{dp,2005}$ and γ_{tp}.

Once we establish the impact of the programme using data from the censuses and the intercensal surveys, we move to the IFLS to examine other outcomes and mechanism variables of interest. None of the provinces had received the programme by 2000 when the third wave of IFLS was fielded. By the time of the IFLS wave 4 in 2007, while the programme had started, it was still in its initial stages and none of the provinces had been covered completely. By the time of the fifth wave of the IFLS, all the provinces included in the IFLS surveys had been covered. As a result, in contrast to data from the IPC and SUPAS, we do not have distinct exposed and control provinces in the IFLS and, therefore, cannot use the $Post_t \times Treat_p$ identification strategy laid out in (1). However, the IFLS, besides the in-depth information on individuals and households, has one more advantage that helps the identification of the programme impacts. The IFLS provides geographical identifiers for communities that are smaller geographical units than districts. This allows us to use variations in pre-programme kerosene usage at a finer level to identify the impact of the programme. We begin by estimating the following specification:

$$Y_{icpt} = \alpha + \beta_1 \times Post_t \times Kero_{cp,2005} + \tau_t \times Kero_{cp,2005} + \gamma_{tp} + \delta_{cp} + \varepsilon_{icpt} \quad (3)$$

where c denotes the community recorded in the IFLS survey. $Kero_{cp,2005}$ is the proportion of households in community c of province p that used kerosene as the primary cooking fuel in 2000. Similar to (2), we include the interaction of the time fixed effects with the pre-programme rate of kerosene usage, sub-district-year fixed effects, and community fixed effects. We cluster the standard errors at the level of the community.

Table 1: Summary Statistics (IPC and SUPAS Data)

Year	1995	2000	2005	2010
Observations	718,837	20,112,539	1,090,892	23,603,049
Number of households	166,033	5,124,971	266,732	6,151,164
Number of districts	200	267	258	268
Number of provinces	17	26	25	26
	Mean [S.D. in brackets]			
Kerosene usage rate	0.35	NA	0.42	0.12
	[0.48]		[0.49]	[0.32]
LPG usage rate in	0.06	NA	0.09	0.46
	[0.24]		[0.28]	[0.50]
Labour force participation rate of men	0.53	0.55	0.53	0.69
	[0.50]	[0.50]	[0.50]	[0.46]
Labour force participation rate of women	0.3	0.38	0.3	0.6
	[0.46]	[0.49]	[0.46]	[0.49]

IPC = Indonesian Population Census, LPG = liquefied petroleum gas, NA = not applicable, S.D. = standard deviation, SUPAS = Intercensal Population Survey of Indonesia.
Notes: Information on cooking fuels was not collected during the IPC of 2000. The SUPAS did not interview the province of Aceh due to the 2004 Indian Ocean earthquake and tsunami that affected the province.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Table 2: Summary Statistics (IFLS Data)

Year	2000	2007	2014
Observations	20,729	21,487	23,226
Number of households	7,360	8,224	8,816
Number of communities	311	310	311
Number of *kecamatan* (regency)	282	284	282
Number of *kabupaten* (district)	152	153	153
Number of provinces	15	15	15
	Mean [S.D. in brackets]		
Kerosene usage rate	0.49	0.4	0.05
	[0.50]	[0.49]	[0.22]
LPG usage rate in	0.12	0.16	0.69
	[0.33]	[0.36]	[0.46]
Labour force participation rate of men	0.74	0.76	0.77
(Work for pay)	[0.43]	[0.42]	[0.42]
Labour force participation rate of women	0.46	0.43	0.41
(Work for pay)	[0.50]	[0.50]	[0.49]
Labour force participation rate of men	0.78	0.78	0.78
(Any kind of work)	[0.42]	[0.42]	[0.42]
Labour force participation rate of women	0.52	0.55	0.54
(Any kind of work)	[0.50]	[0.50]	[0.50]

IFLS = Indonesian Family Life Survey, LPG = liquefied petroleum gas, S.D. = standard deviation.
Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

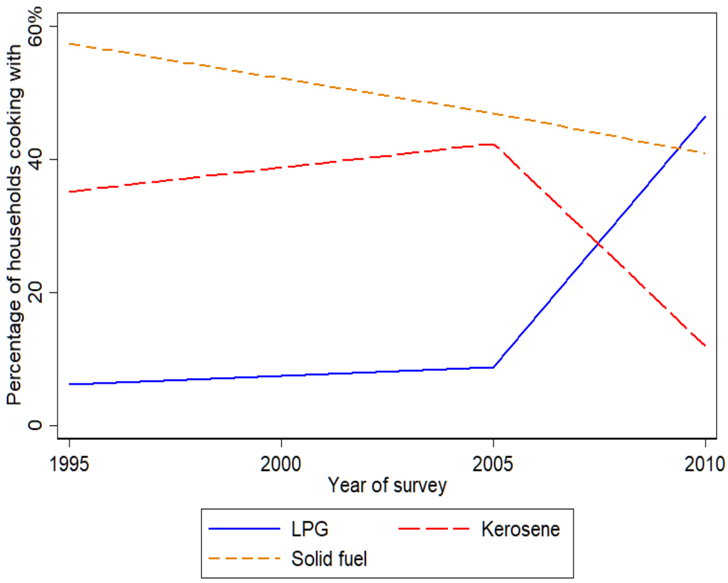
5. Results

5.1. Fuel of choice

Figure 5 reports the change in the proportion of respondent households cooking with different kinds of fuel. The proportion of households using LPG increased substantially from below 10% in 2005 to almost 50% in 2010. We also observe a corresponding decline in the use of kerosene. Consistent with findings from earlier evaluations of the programme, we find that there were no sharp trend breaks in the proportion of households using solid fuels from 2005 to 2010 (Thoday et al., 2018). The number of solid fuel users declined throughout 1995–2010. The LPG conversion programme started in the fiscal year of 2008. Therefore, it seems likely that the increase in the LPG usage rate resulted from the programme. To probe this further, in Figure 6, we break down the LPG usage rate by whether the district was exposed to the programme by the time of the survey. There was an increase in the LPG usage rate in all districts between 2005 and 2010.[21] However, the increase in LPG usage in districts that had received the programme was visibly greater than that in districts that had not received the programme. In Figure 7, we report the change in LPG usage by the pre-programme kerosene usage rate. As expected, we find a larger impact of the programme in districts that had a higher rate of kerosene usage before the programme.

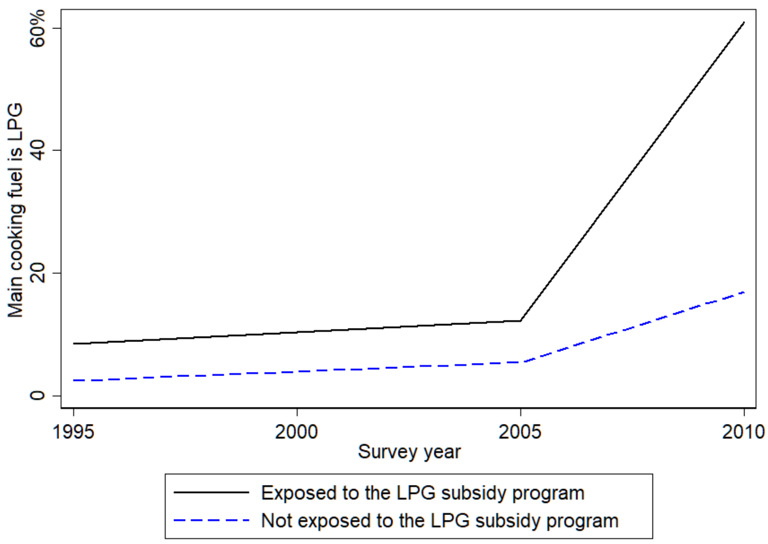
[21] According to our definition of exposure, districts in a province are unexposed until the entire province is covered by the programme. This means that we might categorise some districts that have already received the programme as control districts. As explained in section 3, this will bias our coefficients downwards. This may also explain some of the increase in the LPG usage rate in control districts in Figure 6.

Figure 4: Primary Cooking Fuel, 1995–2010 (IPC and SUPAS Data)



IPC = Indonesian Population Census, LPG = liquefied petroleum gas, SUPAS = Intercensal Population Survey of Indonesia.
Notes: We use information from the IPC of 2010 and SUPAS waves 1995 and 2005 for the figure. The IPC 2000 did not contain information on households' primary cooking fuels.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Figure 5: Primary Cooking Fuel by Program Exposure Status (IPC and SUPAS Data)



IPC = Indonesian Population Census, LPG = liquefied petroleum gas, SUPAS = Intercensal Population Survey of Indonesia.
Notes: We use information from the IPC of 2010 and SUPAS waves 1995 and 2005 for the figure. The IPC 2000 did not contain information on households' primary cooking fuels.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

We verify these findings using a regression framework that controls for district-level differences and province-level changes. Table 3 presents the results. In column (1), we compare the differences in the probability of a household using LPG across time in exposed and control provinces. We find that the households in provinces that received the LPG programme were almost 40% more likely to use LPG after the programme, compared with the control provinces. In columns (2)–(4), we show that this finding is not sensitive to the level of geography for which we include fixed effects and at which we cluster the standard errors. In column (5), using the strongest and our preferred specification from equation (2) that allows us to exploit finer geographical variation, we show that the impact of the programme was much higher in districts with higher pre-programme kerosene usage rates. The interaction coefficient suggests that the high rates of take-up of LPG in districts with high rates of pre-programme kerosene usage rates are driving the results.[22] In column (6), we control for overall labour force participation and FLFP to show that the programme effects were not driven by differences in the broad economic environment across districts. The findings from Table 3 are consistent with the broad trends presented in Figures 6 and 7 – the programme had a causal effect on the LPG usage rate, and this effect was larger in districts with high pre-programme kerosene usage rates.

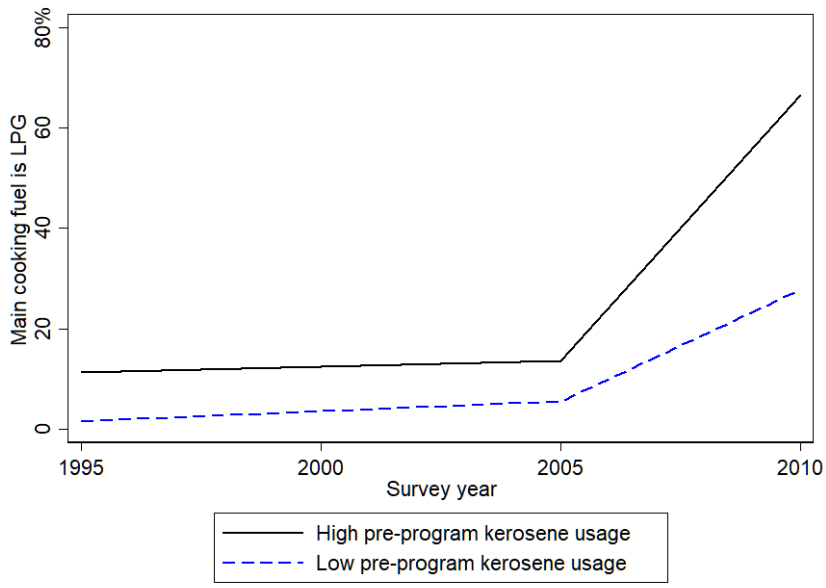
[22] In comparison, as reported in Table A1, the programme did not affect household access to other amenities.

Table 3: Impact on Households' LPG Usage Status (IPC and SUPAS Data)

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Primary Cooking fuel is LPG**					
Post × treat	0.38***	0.38***	0.37***	0.37***	0.07	0.07
	(0.05)	(0.03)	(0.05)	(0.02)	(0.06)	(0.06)
Post × treat × pre-programme kerosene usage rate					0.50***	0.53***
					(0.10)	(0.11)
District FE	No	No	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	No	No
Province-year FE	No	No	No	No	Yes	Yes
Year FE × pre-programme kerosene usage	No	No	No	No	Yes	Yes
Additional district controls	No	No	No	No	No	Yes
SE clusters	Province	District	Province	District	District	District
Mean of DV	0.44	0.44	0.44	0.44	0.44	0.44
Pre-programme kerosene usage rate					0.43	0.43
Observations	25,221,426	25,221,426	25,221,426	25,221,426	24,642,624	24,642,624

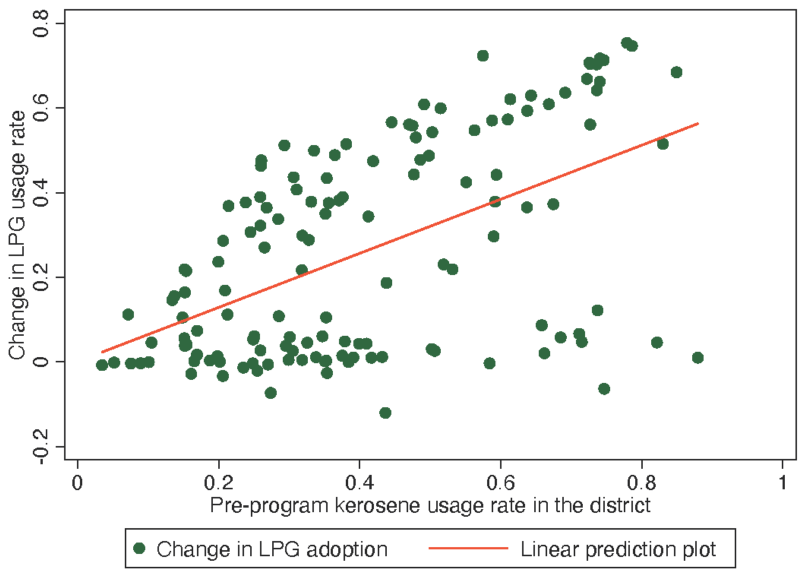
DV = dependent variable, FE = fixed effect, IPC = Indonesian Population Census, LPG = liquefied petroleum gas, SUPAS = Intercensal Population Survey of Indonesia.
Notes: $*$ $p < 0.10$, $**p < 0.05$, $***p < 0.01$. All specifications include the relevant double interactions. Additional controls include district-level pre-programme labour force participation and female labour force participation interacted with Post×Treat.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Figure 6: Primary Cooking Fuel by Pre-Program Kerosene Usage (IPC and SUPAS Data)



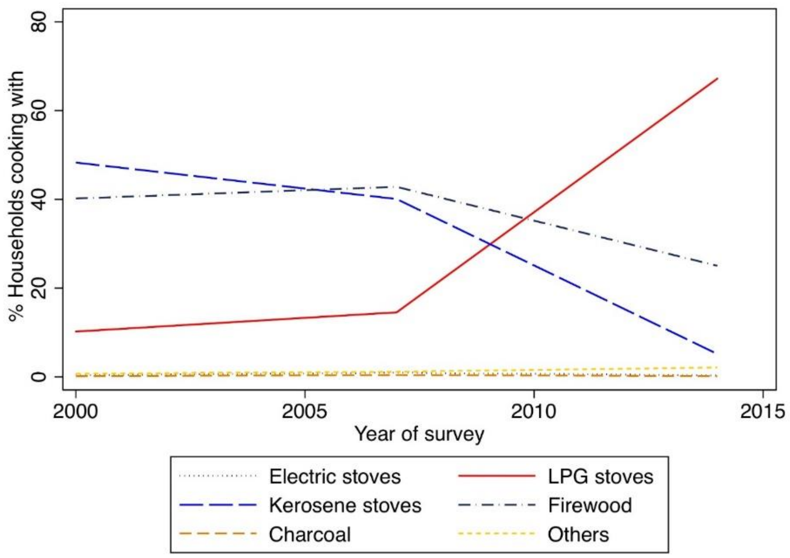
IPC = Indonesian Population Census, LPG = liquefied petroleum gas, SUPAS = Intercensal Population Survey of Indonesia.
Notes: We use information from the IPC of 2010 and SUPAS waves 1995 and 2005 for the figure. The IPC 2000 did not contain information on households' primary cooking fuels.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Figure 7: Change in LPG Usage by Pre-Program Kerosene Usage (IPC and SUPAS Data)



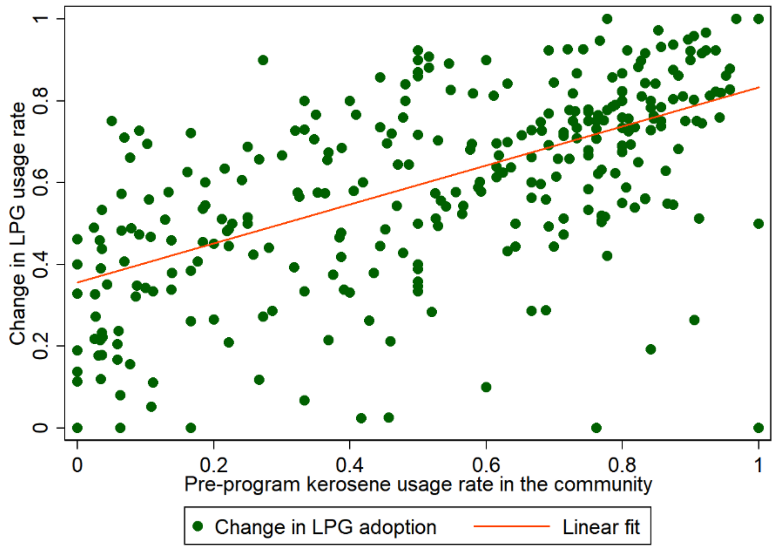
IPC = Indonesian Population Census, LPG = liquefied petroleum gas, SUPAS = Intercensal Population Survey of Indonesia.
Notes: We use information from the IPC of 2010 and SUPAS wave 2005 for the figure.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Figure 8: Primary Cooking Fuel, 2000–2015 (IFLS Data)



IFLS = Indonesian Family Life Survey, LPG = liquefied petroleum gas.
Notes: We use information from the third (2000), fourth (2007), and fifth (2014) waves of the IFLS for the figure.
Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

Figure 9: Change in LPG Usage by Pre-Program Kerosene Usage (IFLS Data)



IFLS = Indonesian Family Life Survey, LPG = liquefied petroleum gas.
Notes: We use information from the third (2000), fourth (2007), and fifth (2014) waves of the IFLS for the figure.
Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

Next, we verify these findings using the community-level variation in the IFLS survey. We present the results in Table 4. According to column (1), controlling for differences across time and time-invariant differences across communities, communities where everyone used kerosene in 2000 were 40 percentage points more likely to be using LPG after the programme in 2014 compared with communities where no one used kerosene in 2000. Since the mean pre-programme kerosene usage rate was 53%, this amounts to an average increase of 21 percentage points across communities. Controlling for household-level time-invariant differences does not change the results. As in Table 3, when we account for time-variant differences across communities with different levels of pre-programme kerosene usage rates, the estimated effect of the programme increases. The impact magnitudes estimated using information from the IFLS are close to those from the IPC and SUPAS, suggesting that estimated impacts are robust across data sets.

Table 4: Impact on Households' LPG Usage Status (IFLS Data)

Variables	(1)	(2)	(3)
	Primary Cooking fuel is LPG		
Post × Pre-programme kerosene usage rate	0.40***	0.46***	0.58***
	(0.042)	(0.052)	(0.048)
Household FE	No	Yes	Yes
Community FE	Yes	No	No
Year FE	Yes	Yes	No
Pre-programme kerosene usage-year FE	No	No	Yes
Province-year FE	No	No	Yes
Mean of DV	0.32	0.32	0.32
Pre-programme kerosene usage rate in the community	0.53	0.53	0.53
Observations	24,564	24,564	24,564

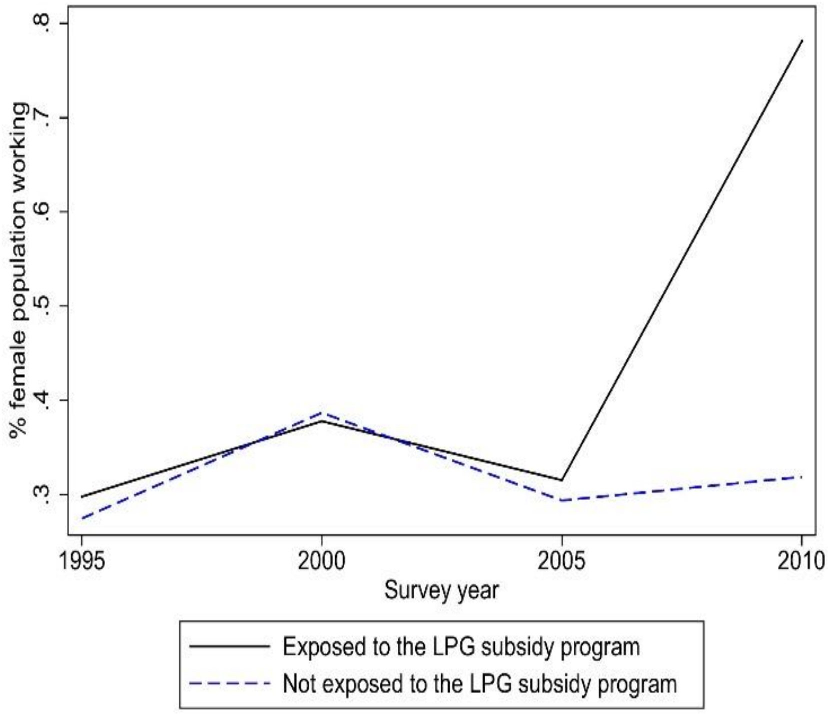
DV = dependent variable, FE = fixed effect, IFLS = Indonesian Family Life Survey, LPG = liquefied petroleum gas.
Notes: * $p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors in parentheses are clustered at the level of the community.
Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

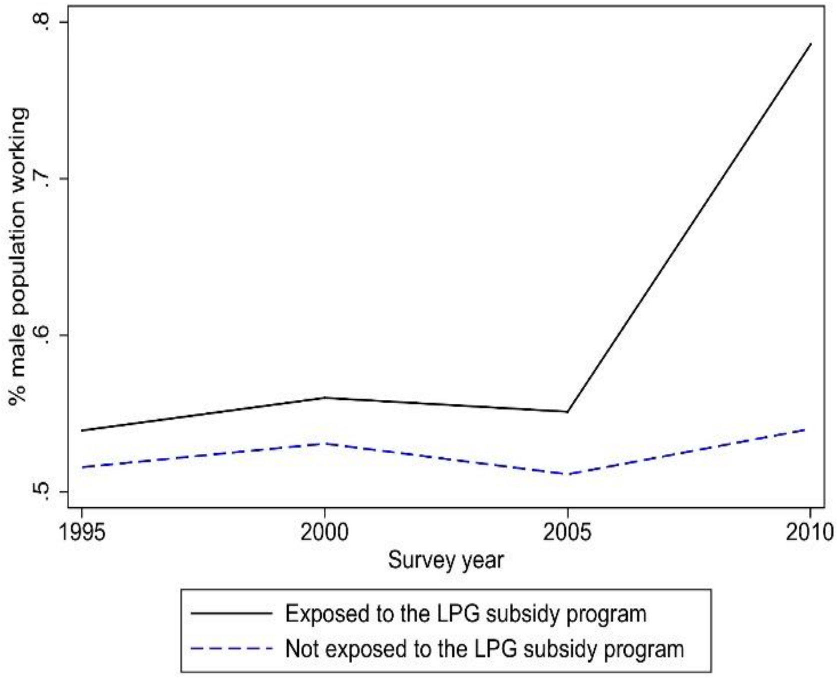
5.2. Labour supply

Figure 11 presents the unconditional trend in the labour force participation of men and women in the exposed and control provinces. The labour force participation in the two groups followed a roughly parallel trend until 2005. However, the labour force participation of both men and women in 2010 was significantly higher in provinces exposed to the programme. Table 5 presents the difference in the labour force participation status, controlling for pre-programme differences across regions. According to column (1), the labour force participation increased significantly in regions exposed to the programme. In column (2), we find that though the labour force participation of the status of both men and women increased over the period, the increase in the labour force participation of women was significantly higher than that of the men. In column (3), we examine the increase in labour force participation by the pre-programme kerosene usage rate. As expected, we find that individuals in regions where the programme had a bigger impact on LPG usage see a higher increase in labour force participation.

Finally, in column (4), we break down the impact on males and females by the pre-programme kerosene usage rate. We find that the programme had a negative effect on the labour force participation rate of males in districts with low rates of pre-programme kerosene usage, but this effect was more than offset by an increase in the FLFP in these districts. The effect was no different for males in districts with higher rates of pre-programme kerosene usage. However, the increase in the labour force participation of women in these regions was much higher. Column (5) shows that including additional controls to account for the differences in the economic environment across districts does not change the results. In summary, we find that men might have decreased their labour force participation by a small amount and women increased their labour force participation in all districts – more so in districts more affected by the programme.

Figure 10: Labor Force Participation by Program Exposure Status (IPC and SUPAS Data)





IPC = Indonesian Population Census, LPG = liquefied petroleum gas, SUPAS = Intercensal Population Survey of Indonesia.
Notes: We use information from the IPC of 2000 and 2010 and SUPAS waves 1995 and 2005 for the figure.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Table 5: Impact on Labour Force Participation Status (IPC and SUPAS Data)

	(1)	(2)	(3)	(4)	(5)
Variables			**Labour force participation indicator**		
Post × Treat	0.31***	0.19***	0.00	-0.07***	0.06
	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)
Post × Treat × Female		0.24***		0.13***	0.13***
		(0.01)		(0.02)	(0.02)
Post × Treat × Pre-programme kerosene usage rate			0.08***	-0.03	-0.12***
			(0.03)	(0.03)	(0.03)
Post × Treat × Female × Pre-programme kerosene usage rate				0.23***	0.23***
				(0.05)	(0.05)
District FE	Yes	Yes	Yes	Yes	Yes
Province-year FE	No	No	Yes	Yes	Yes
Year FE	Yes	Yes	No	No	No
Year FE × pre-programme kerosene usage rate	No	No	Yes	Yes	Yes
Additional district controls	No	No	No	No	Yes
Mean of DV	0.56	0.56	0.56	0.56	0.56
Pre-programme kerosene usage rate			0.44	0.44	0.44
Observations	45,512,808	45,512,808	44,690,116	44,690,116	44,690,116

DV = dependent variable, FE = fixed effect, IPC = Indonesian Population Census, LPG = liquefied petroleum gas, SUPAS = Intercensal Population Survey of Indonesia.
Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses are clustered at the level of the district. All specifications include the relevant double interactions. Additional controls include district-level pre-programme labour force participation and female labour force participation interacted with Post×Treat.
Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Data from the IFLS allow us to examine the impact of the programme on the type of work done by men and women. Table 6 presents the results. Women exposed to the programme in regions that had a high pre-programme usage rate of kerosene were more likely to report ‘working for pay’ as their primary activity in the week before the survey. This is accompanied by a decline in women reporting housekeeping as their primary activity in the previous week. There is a corresponding increase in men reporting housekeeping as their primary activity in the week before the survey, suggesting a reassignment of responsibilities within the household. In terms of all activities performed in the previous week, exposed women report having worked with or without being paid more often. The increase in the labour force participation of the exposed women is also visible in the increase in their probability of having ever held a job in the years preceding the survey (Table A2). Including additional controls to account for the differences in the economic environment across communities or repeating our analysis at the level of the district does not change the results. Taken together, the results suggest an overall sizeable positive effect on the labour force participation of women.

There are two important differences between the estimated labour market impacts of the programme in Tables 5 and 6. First, the impacts are smaller for women when we use information from the IFLS. This could be because the IFLS is representative of only 83% of the Indonesian population living in 13 provinces on the main islands, and misses out on the remoter areas of the country (Strauss, Witoelar, and Sikoki, 2016). It is conceivable that the programme had a bigger impact on the labour force participation of women in these remoter areas. Comparing the labour force participation of women across the summary statistic Tables 1 and 2, it is clear that areas not included in the IFLS but included in the IPC and SUPAS have a lower rate of FLFP. This, in turn, could have been a result of the differences in the household cooking technology used across these regions. The IFLS regions had a higher rate of LPG usage than the IPC and SUPAS regions before the programme. Therefore, the programme might have liberated more women from the burden of household responsibilities in remoter regions.

Second, there appears to be no negative impact of the programme on male labour force participation when we use information from the IFLS. This, too, could be due to the difference in the representativeness of the IFLS compared with that of the IPC and SUPAS. For example, the removal of the kerosene subsidy negatively affected some cottage industries in coastal areas which employed men. Batik textile production, a technique indigenous to Indonesia, suffered in remote coastal regions when the kerosene subsidy was withdrawn because LPG could not be used in place of kerosene to melt the batik wax.[23] This might have affected male employment only in these areas. The IFLS fails to capture this.

5.3. Potential mechanisms

There could be multiple pathways through which the programme might have affected FLFP. In this section, we discuss two important ones.

5.3.1. Time use

According to Table 6, the increase in FLFP has not caused a comparable decline in women's housekeeping. This suggests that women must have found the time to do both – perform housekeeping activities and work for pay. Since it is unlikely that the programme changed the list of housekeeping activities to be performed, women must have been able to perform their housekeeping activities in a smaller amount of time.

Since LPG stoves, as discussed before, are considerably faster, this is not unlikely. Unfortunately, we do not have time-use data for exposed women to be able to examine this mechanism explicitly. However, as discussed earlier, findings from Indonesia and elsewhere suggest that it is definitely a possibility (Rosen and Vincent, 1999; Matly and France, 2003; Greenwood, Seshadri, and Yorukoglu, 2005; Goldin, 2006; Aguiar and Hurst, 2007; de V. Cavalcanti and Tavares, 2008; Coen-Pirani, León, and Lugauer, 2010; Dinkelman, 2011; Clancy et al., 2012; Utomo, 2015; Gurung and Setyowati, 2016; Zhang et al., 2018). The LPG subsidy programme was, in many ways, similar to the Indonesian domestic biogas, but better. The time savings of more than an hour that Gurung and Setyowati (2016) reported for women who switched to domestic biogas for their cooking requirements are net of activities such as cleaning the stable, collecting dung, putting the dung into bio-digesters, putting bio-slurry into the pit, etc., needed to fuel a biogas plant, which require close to 40 minutes. LPG stoves do not require these elaborate processes to keep them running. Therefore, the time saved from switching to LPG might have been higher.[24]

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[23] We thank Mari Pangestu, former Minister of Trade, and Tourism and Creative Economy, for pointing this out.

[24] An audit of energy subsidies and usage in Indonesia also conjectured significant time savings for

Was the time saving enough to generate impacts on labour force participation? Building on the findings from Gurung and Setyowati (2016), even if we use a conservative estimate of 1 hour saved every day, it amounts to 7 hours in a week. Aggregating time saved over a week is especially important in this case since some activities that it replaces, such as the collection of firewood and chopping it into usable blocks, is done on a weekly basis and often performed collectively by the female members of the households. With such activities no longer required, it is plausible that women might have had enough time to work for pay for at least 1 day during the week. Since women so liberated often start in-house microenterprises that do not require a large time commitment (Matly and France, 2003; Ramani and Heijndermans, 2003; Dinkelman, 2011; Utomo, 2015), the time savings should have been enough to generate impacts on FLFP.

Table 6: Impact on Labour Force Participation Status (IFLS Data)

Primary Activities Past Week	(1)	(2)	(3)	(4)	(5)	(6)
	Primary activity		Activities past week			
	Work for pay	Housekeeping	Work for pay	Work with or w/o pay	Housekeeping	Job search
Post × pre-programme kerosene usage rate	0.03	0.03*	0.01	0.02	-0.04	0.00
	(0.027)	(0.014)	(0.026)	(0.026)	(0.030)	(0.014)
Post × pre-programme kerosene usage rate × female	0.07*	-0.07**	0.02	0.03	0.02	0.00
	(0.037)	(0.032)	(0.031)	(0.031)	(0.032)	(0.013)
Estimated effect for females	0.09***	-0.04*	0.04	0.06*	-0.03	0.01
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.01)
Mean of DV	0.59	0.24	0.64	0.65	0.47	0.04
Pre-programme kerosene usage rate	0.53	0.53	0.53	0.53	0.53	0.53
Observations	63,633	63,633	63,838	65,341	63,841	63,837

DV = dependent variable, IFLS = Indonesian Family Life Survey, w/o = without.
Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

women who switched to LPG due to the programme (Kusumawardhani et al., 2017).

Unfortunately, it is difficult to make claims about time use as a mechanism with certainty, without data on time use. Future research should aim to test the hypothesis explicitly. Instead, in the next section, we examine whether there was an improvement in the health of the household members due to the LPG subsidy programme that could have driven the increased labour force participation of women.

5.3.2. Health

Cleaner cooking fuel generates less indoor air pollution. This could have improved the respiratory health of the household members. In fact, much of the motivation behind the large subsidies on cleaner cooking stoves and fuels comes from their potential positive impact on health, in particular the respiratory health of women and young children, through the reduction in indoor air pollution. Further, while better health is a desirable result in itself, it might also affect the labour supply of the household members.

However, despite this perceived potential benefit, the empirical evidence on the respiratory health benefits of using cleaner cooking fuels or technologies is mixed at best (Lam et al., 2012).

Since the IPC and SUPAS do not contain health measures for the respondents, we turn to the IFLS to examine the impact of the programme on health. As a part of the IFLS survey, a professionally trained nurse collects an extensive array of biomarker measurements. In Table 7, we examine the impact of the programme on some of these measures. The programme had no effect on the maximum lung capacity of those exposed to the programme. Amongst other measured health biomarkers, we do not find any significant impact of the programme on the probability of being underweight, grip strength, or systolic or diastolic blood pressure of any adult in the household. The IFLS also collects self-reported information on doctor-diagnosed chronic conditions. Table A3 reports the impact of the programme on the probability of having been diagnosed with certain chronic conditions. Consistent with our earlier findings on lung capacity in Table 7, we find no effect of the programme on respiratory conditions such as asthma and other lung conditions. Exposure to the programme is associated with a small decrease in the incidence of hypertension. Interestingly, we do not observe a corresponding decrease in the systolic and diastolic blood pressure reported in Table A3. Taken together, the findings suggest that there was no major impact of the programme on the health of those exposed to the programme.

However, the switch to LPG might affect FLFP through its effect on the health of the children. For example, Imelda (2018) found that the programme caused a small but significant decrease in the infant mortality rate. If the desired number of living children remained the same over the period, it could have meant a decrease in the number of pregnancies that women had to carry to term. This, too, could have contributed to an increase in their labour force supply decisions. It could also be that women now have to spend a smaller amount of time taking care of children sick due to infant air pollution.

Table 7: Impact on Measured Health (IFLS Data)

Variables	**(1)** **Max. lung capacity**	**(2)** **BMI< 18**	**(3)** **BMI≥ 25**	**(4)** **Grip strength**	**(5)** **Pulse**	**(6)** **Systolic BP**	**(7)** **Diastolic BP**
Post × pre-programme kerosene usage rate	-3.59	0.02	0.02***	1.09	2.93***	1.27	0.73
	(7.21)	(0.02)	(0.01)	(1.19)	(0.64)	(0.97)	(0.61)
Post × pre-programme kerosene usage rate × female	2.96	0.00	0.01	0.54	-1.37*	-1.85*	-0.64
	(5.54)	(0.02)	(0.01)	(0.59)	(0.71)	(0.99)	(0.67)
Estimated effect for females	-0.63	0.02	0.04***	1.63	1.56**	-0.58	0.1
	(6.10)	(0.02)	(0.01)	(1.16)	(0.61)	(1.05)	(0.59)
Mean of DV	341.7	0.14	0.06	28.06	78.15	128.87	79.92
Pre-programme kerosene usage rate	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Observations	65,502	54,326	54,326	41,296	62,324	62,254	62,254

BMI = body mass index, BP = blood pressure, DV = dependent variable, IFLS = Indonesian Family Life Survey, w/o = without.

Notes: * p < 0.10, **p < 0.05, ***p < 0.01. Robust standard errors in parentheses are clustered at the level of the community. All specifications include the relevant double interactions, community fixed effects, province-year fixed effects, and year fixed effects interacted with pre-programme kerosene usage rates.

Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

5.4. Female decision-making power

The major reason for the lack of adoption before the programme seems to be the one suggested by Miller and Mobarak (2013) and alluded to by Pitt, Rosenzweig, and Hassan (2006) – intra-household externalities and gender differences in preferences. In Indonesia, mostly women are in charge of cooking activities. As a result, they bear the maximum brunt of the negative impact of conventional cooking methods. However, expenditure decisions are often taken by the males in the family, who might sometimes be reluctant to spend money on commodities that do not benefit them directly. That is, there might be intra-household externalities of the decision to switch fuels and there might be a difference in preferences across different genders within the household.

Tuntivate (2015) found that women in Indonesia could buy a lower-cost biomass cookstove independently, but needed to consult with their husbands and make a joint decision to purchase a more expensive stove. The study found that women decide alone on small home appliances below an expenditure ceiling, but the decision becomes a joint one above that amount. The threshold for joint decision-making is lower in poorer households. Zhang and Adams (2016) found that while men did little cooking, they had a major role in choosing stoves, especially as new and more expensive cooking technologies appeared. The study found that men do not consider the purchase of cleaner cooking technology a priority. Women reported that getting a new, modern stove was not an easy negotiation with their husbands. Multiple other reports have also pointed out the salience of intra-household bargaining in household cooking technology decisions in Indonesia and elsewhere (Wickramasinghe, 2011; Goodwin et al., 2015; Durix, Carlsson Rex, and Mendizabal, 2016; Mohapatra and Simon, 2017).

It is possible that if women had more say in financial decisions, there might have been a higher rate of adoption of cleaner cooking fuel. To examine this further, we examine the association between a woman’s choice of cooking fuel and her decision-making power within the household. We use two measures of a woman’s decision-making power within the household. The IFLS surveys ask a respondent 18 questions about who amongst their household members makes decisions pertaining to different household matters. For example, one of the questions asked that pertains to financial decision-making is 'In your household, who makes decisions about money for monthly savings?' The respondent can choose more than one person as the decision-maker. For our first measure, we count the respondent as having a complete say in the matter if the respondent reports that he or she makes decisions in the matter alone. For the second measure, we count the individuals as having some say in the matter, if the respondent reports more than one person, including himself or herself, as the decision-makers. We use a count measure of the number of domains in which an individual has complete or some say in the matters. Besides the general measure that aggregates the decision-making responses over the 18 questions, we also define similar measures of financial decision-making using eight questions related to financial matters.

As reported in Table A4, we find that the probability of a woman cooking with LPG (or solid fuels) before the programme was significantly and positively (negatively) associated with the decision-making power of women.[25] Amongst other correlates, the working status of a woman was also associated with a higher likelihood of cooking with LPG. Since the subsidy programme increased FLFP, we might expect the programme to have increased the decision-making power of women in exposed households. We examine the possibility in Table 8. Women affected by the programme report an increase in their decision-making power, especially in financial matters. This change in decision-making power is, possibly, a result of increased workforce participation of women.[26] If the unwillingness of the males to pay for LPG was, in fact, a reason that explained low adoption of the fuel, the increase in the labour force participation and decision-making power of women, especially in financial matters, might ensure that they buy the beneficial technology on their own, even in the subsidy's absence.

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[25] The results remain unchanged if we use complete say in all decisions and financial decisions instead of some say in the decisions.

[26] Wickramasinghe (2011) also conjectured a two-way interrelation between women earning wages and the transitions to cleaner cooking fuels and technologies.

Table 8: Impact on Decision-Making Power of Women (IFLS Data)

Variables	Complete say in: all decisions (score out of 18)	Complete say in: financial decisions (score out of 8)	Some say in: all decisions (score out of 18)	Some say in: financial decisions (score out of 8)
Post × pre-programme kerosene rate	0.25	0.05	-0.07	-0.31*
	(0.23)	(0.12)	(0.32)	(0.16)
Post × pre-programme kerosene × female	0.39	0.35**	0.74**	0.60***
	(0.28)	(0.15)	(0.34)	(0.18)
Estimated effect for females	0.64**	0.40***	0.66*	0.28*
	0.29	0.15	0.34	0.17
Mean of DV	3.52	1.3	10.84	4.58
Pre-programme kerosene usage rate	0.48	0.48	0.48	0.48
Observations	44,456	44,456	44,456	44,456

DV = dependent variable, IFLS = Indonesian Family Life Survey.

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses are clustered at the level of the community. All specifications include the relevant double interactions, community fixed effects, province-year fixed effects, and year fixed effects interacted with pre-programme kerosene usage rates. As an example, one of the questions asked to elicit financial decision-making power is 'In your household, who makes decisions about money for monthly savings?' Response options are respondent, spouse, son, daughter, mother, father, etc.

Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

6. Conclusion

In an attempt to reduce the subsidy burden of kerosene, the Indonesian government sought to replace it with subsidised LPG. Cooking with LPG is less time-consuming than cooking with kerosene or solid fuels. Previous research has found that modern time-saving household technologies have implications on FLFP. Consistent with this, we find large impacts on the FLFP of women exposed to the LPG subsidy programme. The results reinforce the effectiveness of relatively inexpensive policy incentives for the adoption of modern household technology in ensuring greater integration of women in the labour force.

We explore two possible pathways through which a switch to LPG for cooking might have affected the labour force participation of women – better health and time savings. We rule out the health mechanism but do not have adequate data to verify the time-saving mechanism. Based on previous research on the topic, we posit that the time-saving mechanism might have been the pathway through which the program affected FLFP. We leave a more rigorous examination of this mechanism to future research. We show that the programme had benefits for entire households, not just for women. Household consumption expenditure and asset value increased significantly. Women had more decision-making power within the household, especially in financial matters.

The results have important implications on the cost–benefit analysis of programmes of this kind. Focusing on health alone might underestimate the benefits of such programmes. Recent developments in consumer technologies have been impressive not only in their pace but also in the increasing number of features they incorporate. A comprehensive analysis of the benefits of any such technology should examine the effects in a number of dimensions of well-being. Another important take-away pertains to private incentives to adopt modern technology. Even in situations where the private benefits of adoption might surpass the cost for a household, intra-household externalities and differences in preferences within the household might hinder adoption. We must, therefore, revisit the question of the low adoption of welfare-enhancing technology and evaluate the extent to which differences in the preferences of the potential beneficiaries can explain the puzzle. Temporary subsidies that mitigate externalities might go a long way in solving the low-adoption problem in such contexts.

Our analysis has significant limitations. A direct examination of the causal analysis of the impact of the decision-making power of women on the adoption of modern technology is essential in the identification of a possible virtuous cycle of greater adoption and welfare. Similarly, an understanding of the pathways through which technologies such as cooking with LPG affects the labour force participation of women is of crucial importance for designing policies aimed at improving FLFP. Due to data limitations, we leave this to future research.

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Appendix

Table A1: Impact on Households' Amenities (IPC and SUPAS Data)

Variable	(1) Sewage system	(2) Electricity	(3) Piped water	(4) Flush toilet	(5) Finished floor
	Does your household have the access to the following?				
Post × treat × pre-programme kerosene usage rate	0.00	0.06	-0.02	0.06	-0.09**
	(0.06)	(0.05)	(0.07)	(0.06)	(0.03)
Mean of DV	0.54	0.94	0.16	0.6	0.88
Observations	21,548,424	21,550,574	21,551,010	21,547,060	21,527,414

DV = dependent variable, IPC = Indonesian Population Census, SUPAS = Intercensal Population Survey of Indonesia.

Notes: * $p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors in parentheses are clustered at the level of the community. All specifications include the relevant double interactions, district fixed effects, province-year fixed effects, and year fixed effects interacted with pre-programme kerosene usage rates. A finished floor takes the value of 1 if the house some kind of concrete, wood, or stone flooring. It is 0 for earth floors.

Source: IPUMS International (n.d.), https://international.ipums.org/ (accessed 6 September 2019).

Table A2: Impact on Labour Force Participation in Previous Years (IFLS Data)

	(1)	(2)	(3)	(4)	(5)	(6)
	Ever held a job in the previous					
Variables	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**	**6 years**
Post × pre-programme kerosene usage rate	0.04*	0.04*	0.04*	0.04*	0.04*	0.04*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Post × pre-programme kerosene usage rate × female	0.05*	0.06**	0.07**	0.07**	0.07***	0.07**
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Estimated effect for females	0.09***	0.10***	0.11***	0.10***	0.11***	0.11***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Mean of DV	0.72	0.73	0.74	0.75	0.75	0.76
Pre-programme kerosene usage rate	0.53	0.53	0.53	0.53	0.53	0.53
Observations	65,341	65,341	65,341	65,341	65,341	65,341

DV = dependent variable, IFLS = Indonesian Family Life Survey.
Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses are clustered at the level of the community. All specifications include the relevant double interactions, community fixed effects, province-year fixed effects, and year fixed effects interacted with pre-programme kerosene usage rates.
Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

Table A3: Impact on Reported Diagnosis of Health Conditions

(IFLS data, for age above 40 only)

Variables	**(1)** Hypertension	**(2)** Diabetes	**(3)** TB	**(4)** Asthma	**(5)** Other lung conditions	**(6)** Heart conditions	**(7)** Liver problems	**(8)** Stroke	**(9)** Cancer	**(10)** Arthritis
Post × pre-programme kerosene usage rate	-0.01	-0.01	0.00	-0.01	0.01	0.01	0.00	0.01	0.00	-0.03*
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Post × pre-programme kerosene usage rate × female	-0.04	0.03*	0.01	0.00	0.001	0.00	0.01	-0.01	0.01	0.06**
	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)
Estimated effect for females	-0.06**	0.02**	0.01	-0.01	0.01	0.01	0.00	0.001	0.01	0.02
	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Mean of DV	0.21	0.04	0.01	0.03	0.02	0.03	0.01	0.02	0.01	0.11
Pre-programme kerosene usage rate	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Observations	19,252	19,249	19,256	19,256	19,253	19,253	19,256	19,257	19,256	19,252

DV = dependent variable, IFLS = Indonesian Family Life Survey, TB = tuberculosis.

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses are clustered at the level of the community. All specifications include the relevant double interactions, community fixed effects, province-year fixed effects, and year fixed effects interacted with pre-programme kerosene usage rates.

Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

Table A4: Correlates of Fuel Choice and Decision-Making Power of Women in 2000 (IFLS Data)

	(1)	(2)	(3)	(4)	(5)
Variables		**Cooking with**		**Some say in**	
	LPG	**kerosene**	**solid fuel**	**all decisions (score out of 18)**	**financial decisions (score out of 8)**
Some say in all decisions (score out of 18)	-0.004*	-0.003	0.007***		
	(0.002)	(0.003)	(0.003)		
Some say in financial decisions (score out of 8)	0.010**	0.01	-0.021***		
	(0.005)	(0.008)	(0.006)		
Primary activity is work for pay	0.026***	-0.030***	0.004	0.506***	0.182***
	(0.007)	(0.009)	(0.008)	(0.091)	(0.043)
Years of education	0.017***	-0.002	-0.015***	0.087***	0.054***
	(0.001)	(0.002)	(0.001)	(0.012)	(0.005)
Head of the household	0.040***	0.025	-0.075***	-2.785***	-1.113***
	(0.014)	(0.021)	(0.017)	(0.246)	(0.103)
Wife of the head of the household	0.013	0.027*	-0.044***	10.596***	4.342***
	(0.011)	(0.015)	(0.012)	(0.141)	(0.062)
Household head is female	-0.053***	0.065**	-0.011	1.106***	0.503***
	(0.020)	(0.026)	(0.018)	(0.246)	(0.105)
Mean of DV	0.14	0.53	0.33	7.92	3.22
Observations	8,766	8,766	8,766	8,766	8,766

DV = dependent variable, IFLS = Indonesian Family Life Survey.

Notes: * p < 0.10, **p < 0.05, ***p < 0.01. Robust standard errors in parentheses are clustered at the level of the community. Brackets report the p-value of the programme effect on females. All specifications include community fixed effects, province-year fixed effects, and year fixed effects interacted with pre-programme kerosene usage rates. As an example, one of the questions asked to elicit financial decision-making power is 'In your household, who makes decisions about money for monthly savings?' Response options are respondent, spouse, son, daughter, mother, father, etc.

Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

Table A5: Mitigation

Variables	(1) Kitchen outside	(2) Move kitchen inside
Firewood/Charcoal users	0.04***	
	(0.01)	
Switch to a cleaner fuel		0.11***
		(0.03)
Switch to a dirtier fuel		0.02
		(0.07)
Mean of DV	0.25	0.02
Observations	24,586	7,883

DV = dependent variable.
Notes: * p < 0.10, **p < 0.05, ***p < 0.01. Robust standard errors in parentheses are clustered at the level of the community. All specifications include the relevant double interactions, district fixed effects, province-year fixed effects, and year fixed effects interacted with pre-programme kerosene usage rates.
Source: RAND Corporation (n.d.), The Indonesia Family Life Survey (IFLS). https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html (accessed 1 August 2019).

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