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The Effects of Energy Price Changes:
Heterogeneous Welfare Impacts, Energy Poverty, and CO2 Emissions in Indonesia

Abstract

We study the welfare, energy poverty, and CO2 emission implications of energy price change scenarios in Indonesia. Our analysis extends previous analyses of energy price impacts at the household level in several ways. First, by employing a household energy demand system (QUAIDS), we are able to distinguish between first- and second-order welfare effects over the income distribution. Our analysis shows considerable heterogeneity of welfare impacts. For gasoline and electricity, first-order calculations overestimate welfare effects by 10 to 20 per cent for price changes between 20 and 50 per cent. Second, our results point to the ownership of energy-processing durables as another source of impact heterogeneity. Poor households that own these goods may be hit particularly strongly by energy price increases. Third, we extend the welfare analysis beyond the money-metric utility effects and look at energy poverty, which is understood as the absence of or imperfect access to reliable and clean modern energy services. Drawing on the estimated demand function, we find that price increases have substantial effects on energy poverty. Fourth, our analysis explicitly considers the emissions effects of energy price scenarios. We find that reduced household energy demand implies a substantial reduction in emissions. The analysis thus indicates that energy prices may serve as an effective mitigation instrument but also have important adverse welfare effects. The latter can, however, be mitigated by appropriate compensation policies.

Keywords: energy subsidies, climate policy, poverty, distributional effects, energy poverty

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Article Outline

1   Introduction

Fuel and energy prices are subject to government intervention in many low- and middle-income countries, where governments often set domestic energy prices below market levels or impose taxes on transport fuels. Increasing energy accessibility for the poor is one main motivation for subsidising it, while fuel taxation is a popular measure to internalise externalities at relatively low levels of distortion. In recent years, climate change mitigation has emerged as an additional reason to regulate energy prices. Such regulation typically affects

substantial shares of governments' budgets, and the abolition of fuel subsidies in developing countries has frequently been advocated as a win-win policy which reduces market distortions and internalises negative climate externalities. Additionally, a large set of studies finds fuel subsidy cuts to be progressive as they impact richer households more than poorer households (Arze del Granado et al. 2012; Clements et al. 2013; Sterner 2011). Nevertheless, fuel subsidies remain popular and attempts to cut them usually meet with fierce public resistance. This might be partly attributed to poor (ex ante) communication of potential compensation schemes, but it also raises the question of whether corresponding welfare effects that occur at the household level have so far been properly understood.

Theoretically, the direct welfare effects of energy price changes at the household level depend on the magnitude of the price change, the relative importance of energy items in a household's consumption bundle, and the ability and willingness to substitute something else for the more expensive good. In addition, price changes might affect production costs and hence the prices of other goods, leading to indirect effects that will eventually affect labour demand and wages (Fullerton 2009, 2011). In this paper, we analyse the welfare impacts of energy price changes using a partial equilibrium approach based on a detailed empirical model of household energy demand in Indonesia. Even though our model does not capture potential indirect effects, we prefer it to a general equilibrium model for three reasons. First, the majority of energy subsidies take the form of fixed prices for consumers, such that indirect effects through wages and employment are unlikely to be of major importance in the short run. Second, the use of a computable general equilibrium (CGE) model would create a high demand for empirically unavailable parameter values. Third, the disaggregated evaluation of different energy items is a distinct strength of our analysis, and something which would not be possible within a general equilibrium framework.

The empirical context of our study is Indonesia, a country with a long tradition of regulating consumer energy prices and a recent change in subsidy policies, facilitated by dramatically falling oil prices. Historically, the scenario of fuel subsidy abolition has received much attention on the country's political agenda, primarily because of the large potential for efficiency and distributional gains on the one hand and the political risk of abolishing subsidies on the other. This makes the country an ideal case for studying the welfare implications of energy price changes in a detailed fashion. We analyse a scenario of rising energy prices for a set of commercial energy items used by households and estimate the impact on household welfare, energy poverty, and demand-related carbon emissions. Our findings are relevant for the country's policymakers as, with a resurging oil price, the ongoing phasing out of fuel subsidies, and some domestic climate policy ambitions as reflected by the Nationally Determined Contribution (NDC) to the Paris Agreement, energy prices are likely to rise for Indonesian households in the future.

Previous first-order partial equilibrium studies on the impact of energy pricing in low- and middle-income countries have mainly concluded that fuel subsidy cuts or tax increases

tend to be progressive, primarily because poorer households tend to spend relatively little on transport fuels.[1] In earlier work on Indonesia, Pitt (1985) found that kerosene subsidies disproportionally benefited urban and wealthy households. More recently, Olivia and Gibson (2008) have estimated a five-good household energy demand system for Indonesia, finding that kerosene yields the highest marginal tax returns. However, as soon as they incorporate inequality aversion into their optimisation problem, kerosene is outperformed by liquefied petroleum gas (LPG) and gasoline. Datta (2010) calculates own- and cross-price elasticities for demand for four energy items and finds strong behavioural responses for transport fuel, kerosene, and LPG. Specifically, he finds relatively high substitution rates for LPG demand, and disproportionally large responses of poor households to price changes in transport fuel and kerosene. Our study also contributes to the literature that assesses energy price effects in Indonesia using CGE models. The main conclusion to be drawn from this literature is that taxing transport fuels tends to be progressive (Clements et al. 2013; Yusuf and Resosudarmo 2008), while kerosene taxation has regressive effects (Yusuf and Resosudarmo 2008). Another insight generated is that it is important to incorporate revenue spending into the analysis, as it can substantially change the results (Dartanto 2013; Lasserve et al. 2015).

We argue that by incorporating additional outcomes into the impact analysis of energy pricing reforms, we contribute to the existing literature in several ways. First, based on a detailed household expenditure survey we estimate a household energy demand system (QUAIDS) to distinguish between first- and second-order welfare effects over the income distribution. Our analysis shows considerable heterogeneity of welfare impacts. For gasoline and electricity, first-order calculations overestimate welfare effects by 10 to 20 per cent for price changes between 20 and 50 per cent. This holds particularly for gasoline and for richer households, which react more strongly to price changes. Second, our results reveal that the ownership of energy-processing durables such as motor transport vehicles, electric appliances, and cooking stoves is another source of impact heterogeneity. Poor households that own these goods may be hit particularly heavily by energy price increases. Third, we extend the welfare analysis beyond the money-metric utility effects and look at energy poverty, which is understood as the absence of or imperfect access to reliable and clean modern energy services. By drawing on the estimated demand function and the resulting price elasticities, we find that price increases have substantial effects on energy poverty. Fourth, our analysis explicitly considers the emissions effects of the energy price scenarios. Although these effects are estimated with some uncertainty, it turns out that reduced household energy demand implies a substantial reduction in emissions.

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1   Sterner (2011) presents a collection of mostly first-order, partial-equilibrium studies on the impact of transport fuel taxes on the poor in Mexico, Costa Rica, China, India, Ethiopia, Ghana, Kenya, and Tanzania, and on the impact of reducing transport fuel subsidies in Iran. Arze del Granado et al. (2012) provide a review of fuel subsidies for 20 countries and find that the top income quintile receives as much as six times more in subsidy payments than the bottom quintile.

The remainder of the paper proceeds as follows. We first describe, in Section 2, the current situation regarding consumer energy prices and the energy subsidy scheme for consumers in Indonesia. Section 3 then presents the price and survey data as well as some descriptive statistics. In Section 4, we describe the theoretical and empirical models underpinning our welfare analysis. Section 5 presents the results, and Section 6 concludes with some policy recommendations.

2   Consumer Energy Prices and Subsidies in Indonesia

The Indonesian government has traditionally set energy prices for households below international market levels. The subsidy regime is intended to increase energy-poor households' access to energy and has been the dominant domestic energy policy instrument for decades. In recent years, the high costs of the subsidies have put considerable pressure on public finances – much more so since 2009 when the country became a net oil importer and left OPEC. Today, Indonesia is more oil dependent than ever before. From 2000 to 2013, per capita final energy consumption increased by over 55 per cent (MEMR 2014), and fuel subsidies likely played a role in this increase. As a reaction to the fiscal pressure, the government tried to implement subsidy reductions in 2005, 2008, and 2013, when rising oil prices pushed up government fuel subsidy expenditures. In late 2014, the newly elected government announced a complete phaseout of fuel subsidies in the coming years. As part of all these recent subsidy reforms, the government complemented fuel subsidy cuts with pro-poor compensation programmes, which helped it gain public acceptance.[2]

Figure 1 shows the nominal energy prices for electricity, gasoline, kerosene, and LPG, respectively, from 2008 onwards.[3] Two findings become immediately apparent from the four subgraphs. First, for most of the energy items, the prices follow a step functional form, indicating the government's manual price-regulation regime. Second, prices evolve differently over time, which is a sign of substantial price discrimination, even within energy items. We focus explicitly on the main energy items that households use, including electricity and fuels such as gasoline, kerosene, and LPG. Due to data limitations we have not been able to incorporate two widely used traditional fuels – namely, firewood and biomass.

In the electricity sector, price discrimination takes place across households, businesses, and industry. As indicated by the step functional form, all prices are manually regulated, and households pay the lowest price compared to industry and business. The government implements the price regime through a block tariff schedule, which is progressive with respect to electricity demand. With an estimated production price of IDR 1,200 per kwh (ap-

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2   The compensation package for the 2013 reform, for instance, included short-term unconditional cash transfers, increased food distribution, and additional spending on infrastructure programmes.

3   Data on retail energy prices are from the Ministry of Energy and Mineral Resources.

proximately EUR 0.07 at 2015 exchange rates), only a few customers pay an unsubsidised price and fees for households as low as IDR 150 reveal the dimension of subsidies paid in this sector.

The upper-right graph in Figure 1 sets out the prices for different types of gasoline, the main transport fuel in Indonesia. Different products with varying octane qualities exist, but low-quality gasoil, mainly used for motorcycles, dominates the market. While the higher-quality gasoline fuels (92 and 95 octane) float more freely with and are closer to international market prices, the government has fixed prices of lower-quality gasoline at comparatively low levels. For the latter, we observe differences between official retail prices and measured prices at the consumer level for rural and urban areas, respectively. Higher transport costs and additional trading margins in the informal market explain the relatively high rural consumer prices.

Kerosene, a multipurpose fuel used for cooking and lighting, has not seen a change in retail prices since 2008, but rural consumers have nevertheless paid an increasingly higher price in recent years. Recent subsidy reforms have abolished kerosene subsidies for industrial consumers. Overall, the relatively limited government action within this sector can be partly ascribed to the decreasing use of kerosene, which is increasingly being replaced with LPG.[4] LPG is the most commonly used fuel for cooking and comes in different bottle sizes with corresponding price regulations. As Figure 1 illustrates, the smallest bottle size (3 kg) is the most highly subsidised and has not undergone any price change in recent years. Prices for 12 kg bottles increased with the most recent energy reform, while the price of 50 kg bottles shifts with market prices. Like transport fuels, LPG is, on average, more expensive in rural than in urban areas.

When international oil prices are low, gasoline subsidies may be completely phased out for the period in question. However, when oil prices start to rise again and subsidies are abolished as politically communicated, households will face non-marginal price increases that, depending on the scenario on international markets, could reach 100 per cent and more.

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4   In 2007 the government launched a kerosene-to-LPG transition programme that included the disbursement of more than 48 million free LPG start-up packages and small, subsidised LPG tanks (3 kg).

Figure 1. Nominal Energy Prices Over Time
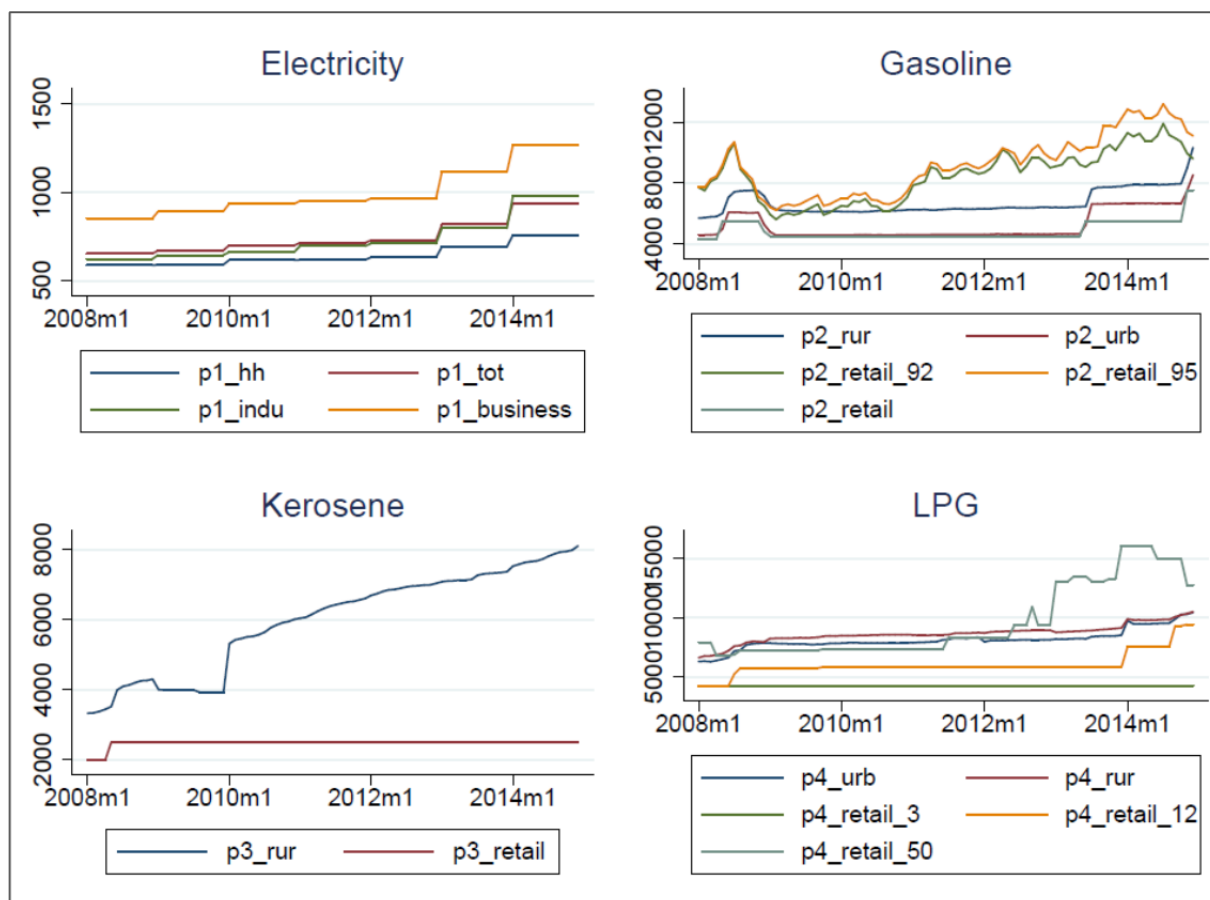
3   Data

We use household expenditure data from the Indonesian Survei Sosial Ekonomi Nasional (SUSENAS), a cross-section survey collected annually by Badan Pusat Statistik (BPS) Indonesia.[5] By drawing on the survey data and applying the national poverty lines provided by BPS Indonesia, we find that the poverty rate in Indonesia was 12 per cent in 2013, with the majority of the poor living in rural areas (see also Table 1).[6] The SUSENAS survey comes with a detailed expenditure module containing reported expenditures and quantities for electricity (in kwh), gasoline (in litres), kerosene (in litres), and LPG (in kg). In addition, the module reports other expenditures for transport, including spending on public transport, airfares, and marine transport.

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[5]   For descriptive purposes and the welfare analysis we use the March 2013 data. For the estimation we use a pooled dataset for the years 2009–2013. The provision of data by Badan Pusat Statistik (BPS) is gratefully acknowledged.

[6]   The national poverty line is relatively low. In 2010, a year for which both international and national poverty rates are reported by the World Bank, the poverty rate was 11.3 using the national poverty line and 15.9 using the int. $1.9 poverty line.

Based on these data, Figure 2 shows household expenditures for all energy (electricity, gasoline, kerosene, LPG, other transport, and firewood), "modern" energy (electricity, gasoline, kerosene and LPG; used in the later analysis), transport energy (gasoline and other transport), and domestic energy (electricity, kerosene, LPG, and firewood) items distributed over percentiles of total household per capita expenditure.[7] Due to the discrete nature of the decision to obtain major energy-consuming durables, we distinguish between the average user in the sample, including those with zero demand (demand ≥ 0), and the average user with strictly positive demand (demand > 0). This is a simple approximation of the above-mentioned heterogeneity in energy spending patterns between households that, in contrast, may be similar in terms of household per capita income. In the case of the aggregated energy expenditures presented in Figure 2 this hardly makes a difference, while it is very relevant to the analysis of single energy items.

In general, energy expenditures rise over the expenditure distribution, an increase which appears to be driven by transport expenditures. Access to modern domestic energy sources is widespread, though some households below the 20th percentile are without access. Even among this group, more than 90 per cent can access alternatives to solely traditional energy. Figures 4 and 5 set out expenditure patterns for electricity, gasoline, kerosene, and LPG for rural and urban households, respectively. Electricity grid access in Indonesia is high, with 76 per cent of households connected in 2012 (IEA 2014). In our survey data, electricity use also includes local power supply and diesel generators, and we even observe that 90 per cent of households have non-zero electricity demand. Electricity budget shares, on average, increase with income and are one percentage point higher for urban than for rural households.

According to figures 4b and 5b, moving from the poorest to the richest households doubles gasoline expenditure shares, for rural and urban households alike. Yet among households that use gasoline, expenditure shares remain stable and for this subgroup, the first-order distributional effects of a gasoline tax would show a remarkably different pattern. Thirty per cent of the poorest households use gasoline, mostly as an input for motorcycle transport. Kerosene is now the least popular fuel in Indonesia, with only 30 per cent of households exhibiting positive demand. It is still more widely used in rural areas and, somewhat surprisingly, not just by low-income households but also, with slightly higher budget shares, by middle- and higher-income households. While kerosene is a multipurpose fuel, LPG and firewood are mostly used for cooking. In rural areas, LPG shows a very similar expenditure share pattern to kerosene, while usage rates among urban households are substantially higher and expenditure shares are decreasing in wealth. According to figures 4e and 5e, low-income households depend heavily on firewood and, overall, rural households use more firewood than urban households. For comprehensiveness, we also draw budget shares for the transport residual category, including transport modes such as local public

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7   Nonparametric distributional curves are calculated with kernel-weighted local polynomial smoothing using an Epanechnikov kernel function with degree 0 and bandwidth 1.15.

transport and air travel. The latter likely drives the distinct jump in expenditure shares for the richest expenditure quantile, which is relatively large for rural households. Other minor transport energy items are motor oils and diesel, even though household consumption of the latter is negligible in Indonesia.

Typically, owning an energy-processing durable is a necessary condition for positive energy demand. Private transport is a case in point for our empirical setting, where the possession of private transport vehicles (specifically motorbikes) explains a large part of gasoline demand. Once households own a motorbike, they tend to spend a similar share of their income on gasoline, irrespective of their income levels. Table 1 illustrates this relationship and depicts poverty status, ownership of a means of private transport, and gasoline expenditure shares across several population subsamples. Out of all urban and rural households, 65.0, 74.0, and 58.2 per cent possess some kind of private transport vehicle, usually a motorbike. Poor households show a 40 per cent lower ownership rate but only slightly lower gasoline expenditure shares than the non-poor. Urban-poor vehicle owners spend an even higher budget share on gasoline than the urban non-poor and, interestingly, we do not find major differences in transport-related energy demand between rural and urban households.

Our analysis of energy demand patterns reveals interesting insights on an often-overlooked dimension of the distributional analysis of energy price changes: energy poverty. The International Energy Association defines energy poverty as "the lack of access to modern energy services. These services are defined as household access to electricity and clean cooking facilities [e.g. fuels and stoves that do not cause air pollution in houses]" (IEA 2014).[8] Hence, our focus is on the domestically used energy items electricity, kerosene and LPG, for which expenditure information is available in the household survey. We transform quantities of energy items into physical, normalised units (kilograms of oil equivalent, kgoe) and aggregate them to household energy use per capita.

Similarly to conventional poverty measurement, energy poverty measures depend heavily on the underlying poverty line. Thus, in the following, we define two poverty lines. Our first energy poverty line (EPL 1) has a cut-off of 50 kgoe of final annual energy per capita. This poverty line is solely based on modern fuels used for cooking and a minimum amount of electricity, similarly to that in Modi, Vijay et al. (2005). We define our second energy poverty line (EPL 2) according to the expenditure poverty line, inspired by Foster et al. (2000).[9] We refrain from calculating a transport poverty line because of conceptual and empirical issues,

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8   A wider definition of energy poverty could also include transport-related energy or the quality and performance of the energy use as discussed in Angelou et al. (2013), but this is beyond the scope of our study.

9   We do this by transforming demanded quantities of all modern energy items into kgoe and performing a nonparametric kernel-weighted local polynomial regression of the quantity used per energy item on total household expenditures per capita for the reference year 2013. The calculated value at the per capita expenditure poverty line can then be directly interpreted as our energy poverty line, at which we calculate FGT energy poverty indices.

such as the difficulty of comparing urban and rural energy needs and the missing public transport data. Table 2 displays the calculated Foster-Greer-Thorbecke (FGT) energy indices and the per capita energy poverty line EPL 2, which is considerably lower than EPL 1 at approximately 22 kgoe. Although this poverty line is at a relatively low level, the national energy poverty rate is close to 30 per cent, primarily as a result of the rural energy poverty rate of 43 per cent. To be clear, there are many non-income-poor households which do not use more modern energy than the average household at the poverty line. Based on EPL 1, the national energy poverty rate is above 60 per cent. Since many, and particularly rural, households use firewood for cooking and we have excluded it from the analysis, the magnitude is not particularly surprising.

Table 1. Gasoline Demand, Vehicle Ownership, and Poverty

	pop %	w (d>=0)[a]	w (d>0)[b]	priv tr[c]	Moto[d]
All	1	0.035	0.053	0.65	0.636
Urban	0.426	0.038	0.051	0.74	0.727
Rural	0.574	0.032	0.055	0.582	0.568
Poor	0.117	0.019	0.052	0.371	0.365
Non-poor	0.883	0.037	0.053	0.686	0.672
Urban poor	0.039	0.025	0.053	0.462	0.459
Urban non-poor	0.387	0.039	0.051	0.768	0.754
Rural poor	0.078	0.017	0.051	0.326	0.318
Rural non-poor	0.497	0.035	0.056	0.623	0.607

Source: Authors' computation based on SUSENAS (2013).
a   Average budget share over population including zero demand
b   Average budget share over population excluding zero demand
c   Ownership rate for private transport vehicles
d   Ownership rate for motorcycles
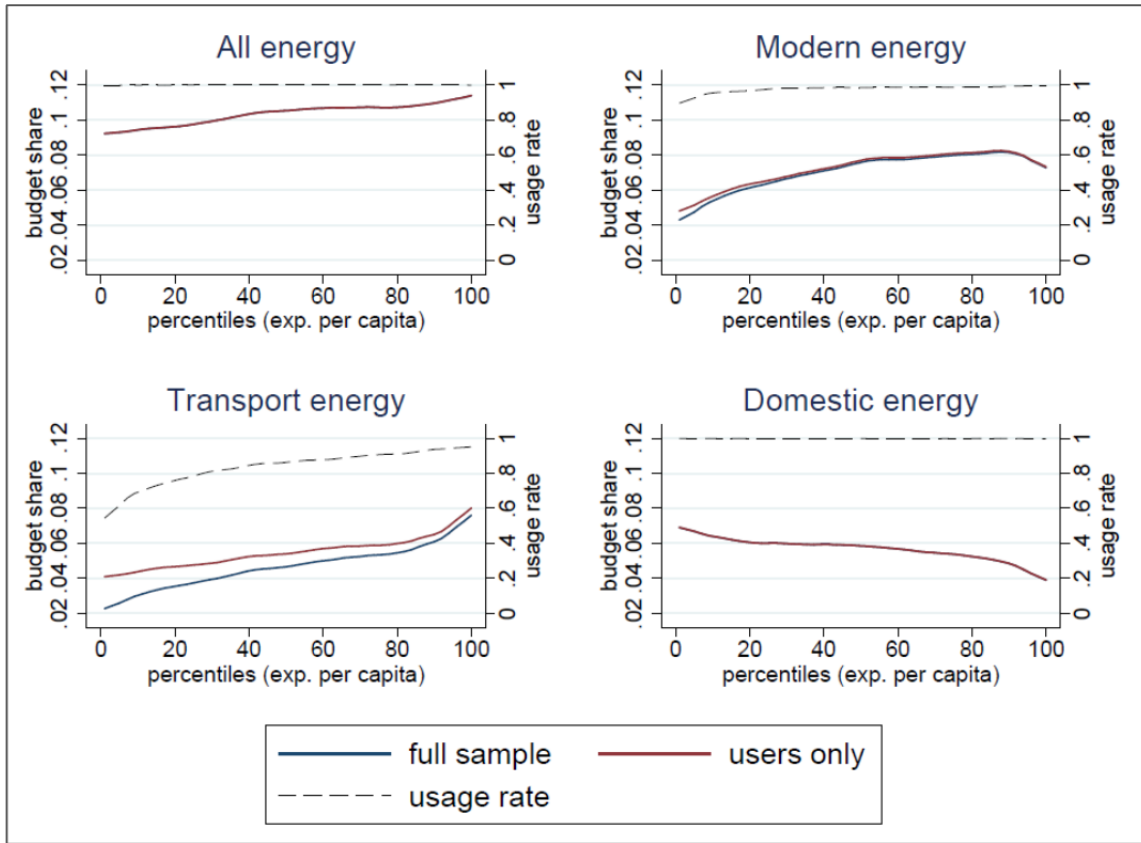
Figure 2. Energy Expenditure Shares

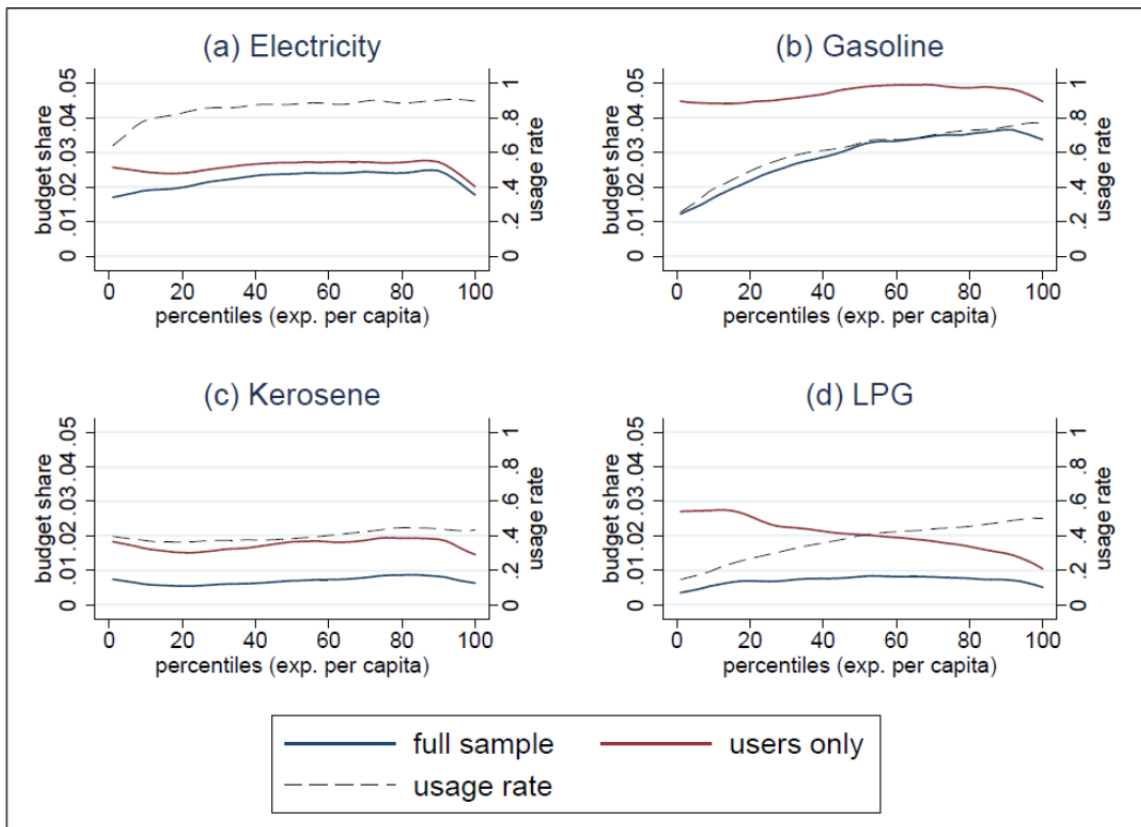**Figure 3. Rural Energy Expenditure Shares and Usage Rates**

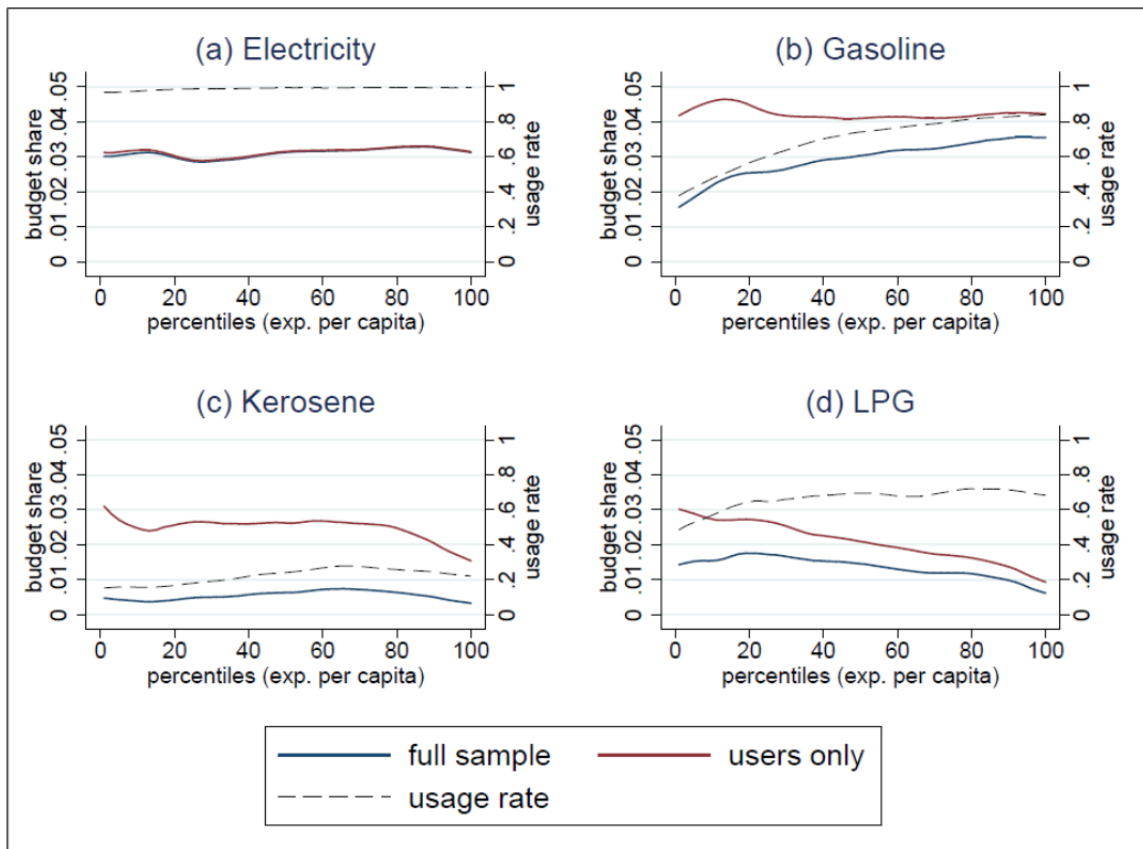**Figure 4. Urban Energy Expenditure Shares and Usage Rates**

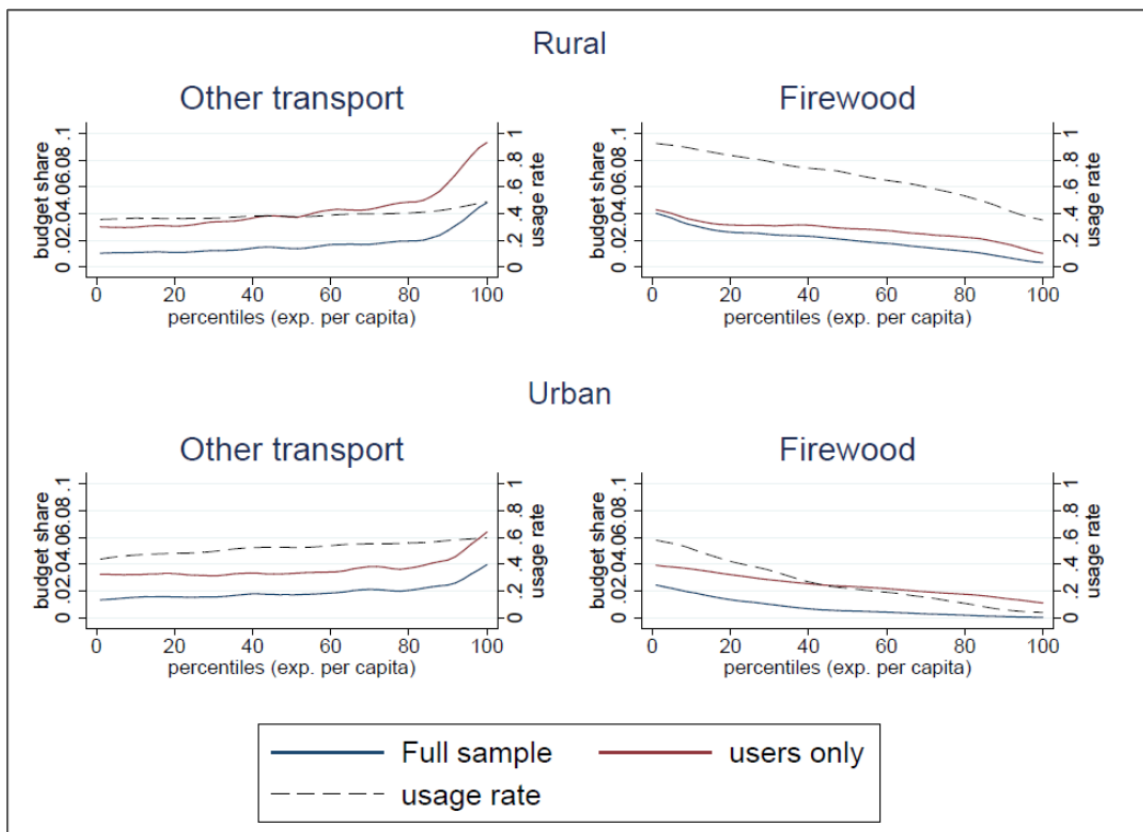**Figure 5. Urban and Rural Energy Expenditure Shares and Usage Rates**

Table 2. Energy Poverty

	FGT								
	National			Rural			Urban		
	0	1	2	0	1	2	0	1	2
EPL 1	0.61	0.32	0.22	0.75	0.44	0.31	0.43	0.16	0.09
EPL 2	0.29	0.14	0.09	0.43	0.22	0.15	0.11	0.04	0.02

EPL 2 poverty line: 21.82 kgoe

4 Methodology

4.1 Demand System

There is an extensive literature on the estimation of demand functions based on economic theory. Since the seminal work of Stone (1954), a significant amount of research has been produced, with Deaton and Muellbauer's (1980b) Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980a) and the quadratic extension of the AIDS, the QUAIDS by Banks et al. (1997), among the more prominent examples. The QUAIDS estimation has been applied to the energy context by West and Williams III (2004), Labandeira et al. (2006), Nikodinoska and Schröder (2016), and Tiezzi and Verde (2016). To our knowledge, no demand system specification of this form has so far been applied to the energy context in low- and middle-income countries. For India, Gundimeda and Kohlin (2008) estimate a linearly approximated AIDS differentiated by income for rural and urban households separately. They report a full range of substitution elasticities for a four-good energy demand system but no welfare effects. More recent developments in the field have tended towards even higher nonlinearity in parametric systems (Lewbel and Pendakur 2009). For our analysis we use the well-established QUAIDS framework, since observed Engel curves appear to be well approximated by a quadratic relationship between budget shares and logarithmic transformed expenditures. Rank three quadratic logarithmic budget share systems have an indirect utility function that takes the following form:

$$\ln V = \left\{ \left[\frac{\ln x - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1} \qquad \text{ZEqn1} \quad (1)$$

The price indexes $\ln a(p)$ and $b(p)$ are defined as:

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \qquad \text{ZEqn2} \quad (2)$$

$$b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \qquad \text{ZEqn3} \quad (3)$$

The term $\lambda(p)$ in the indirect utility function is a differentiable, homogeneous function of degree zero of prices p and defined as:

$$\lambda(p) = \sum_{i=1}^{n} \lambda_i \ln p_i$$

ZEqn4   (4)

With $\sum_i^n \lambda_i = 0$ the derived expenditure share system is:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left[\frac{x}{a(p)}\right] + \frac{\lambda_i}{b(p)}\left\{\ln\left[\frac{x}{a(p)}\right]\right\}^2$$

ZEqn5   (5)

where w_i is the share of commodity (group) i of total expenditures x. To be consistent with utility maximisation, the following restrictions need to hold:
Adding-up

$$\sum_{i=1}^{n} \alpha_i = 1; \quad \sum_{i=1}^{n} \gamma_{ij} = 0; \quad \sum_{i=1}^{n} \beta_i = 0; \quad \sum_{i=1}^{n} \lambda_i = 0$$

ZEqn6   (6)

Homogeneity

$$\sum_{j=1}^{n} \gamma_{ij} = 0$$

ZEqn7   (7)

Symmetry

$$\gamma_{ij} = \gamma_{ji}$$

ZEqn8   (8)

Budget elasticities can be derived from the share equation:

$$e_i = \frac{\mu_i}{w_i} + 1$$

ZEqn9   (9)

With

$$\mu_i = \frac{\partial w_i}{\partial \ln x} = \beta_i + \frac{2\lambda_i}{b(p)}\left\{\ln\left[\frac{x}{a(p)}\right]\right\}$$

ZEqn10   (10)

The uncompensated price elasticity is given by:

$$e_{ij}^{u} = \frac{\mu_{ij}}{w_i} - \delta_{ij}$$

ZEqn11   (11)

With

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_i} = \gamma_{ij} - \mu_i\left(\alpha_j + \sum_{k}^{n} \gamma_{jk} \ln p_k\right) - \frac{\lambda_i \beta_j}{b(p)}\left\{\ln\left[\frac{x}{a(p)}\right]\right\}^2$$

ZEqn12   (12)

and δ_{ij} is the Kronecker delta. Compensated price elasticities are derived using the Slutsky equation:

$$e_{ij}^{c} = e_{ij}^{u} + e_i w_j$$

ZEqn13   (13)

In household expenditure data, recorded zero expenditures are a common problem. However, the possible reasons, infrequency of purchase or corner solutions, are hard to distinguish empirically. The literature usually identifies this data issue as censored, although censoring may only be a special case of the underlying data generation process. We stick to this discussion and use censored as a synonym for zero observations in budget share data. Apart from the recent use of Full Information Maximum Likelihood (FIML) estimation (Chen and Yen 2005), the suggested solutions in the literature are based on Heckman's two-step approach (Heckman 1979). Heien and Wessells (1990) applied the two-step approach to the demand context, but attracted criticism for being inconsistent in later work. Shonkwiler and Yen (1999) prove this inconsistency, showing the statistically correct way to obtain elasticity estimates in censored system settings. First, a household-specific probit model is estimated with the outcome of one if the household consumes good i and zero otherwise. For each household, the standard normal probability density function (pdf) and the cumulative distribution function (cdf) are calculated by regressing w_i on a set of independent variables z_i. Second, the pdf and the cdf are integrated into the system of equations as follows:

$$w_i^* = \Phi w_i + \varphi_i \phi$$

<div align="right">ZEqn14   (14)</div>

In contrast to Heckman (1979), this approach makes use of the full sample in both steps of the estimation process. According to Shonkwiler and Yen (1999), the estimation of a censored system requires a procedure that uses the whole sample since each dependent variable may have a different pattern of censoring. The elasticity formulas (relative to quantities) for the QUAIDS change as:

Expenditure elasticity

$$e_i^* = \frac{\Phi(\mu_i)}{w_i} + 1$$

<div align="right">ZEqn15   (15)</div>

Price elasticity

$$e_{ij}^* = \frac{\Phi(\mu_i)}{w_i} + \phi \tau_{ij}(1 - \frac{\varphi_i}{w_i}) - \delta_{ij}$$

<div align="right">ZEqn16   (16)</div>

The respective expenditure and price elasticities, e_i and e_{ij}, are derived under the modified system (13). This two-step methodology has been applied in food-demand contexts by Yen et al. (2002) and Ecker and Qaim (2011), among others, but not yet for energy demand.

4.2 Welfare Effects

Since the literature on the welfare impacts of subsidy reforms focuses on first-order effects, as in Sterner (2011), we are interested in the necessity of calculating second-order effects that take into account demand substitution. The first-order effects (FO) require only the observed demand and no additional information on substitution behaviour due to price changes (Deaton and Muellbauer 1980b; Feldstein 1972; Stern 1987):

$$FO = \sum_{i=1}^{n} w_i \frac{\Delta p_i}{p_i^0} \qquad\qquad \text{ZEqn17 \quad (17)}$$

More exact welfare measures, incorporating substitution effects, were proposed early on by Hicks (1939) together with the compensating and equivalent variation measures. The difference between first-order welfare measures approximated by the budget share and more exact second-order approximations incorporating household demand responses are well documented in Banks et al. (1996). As they demonstrate, the difference between first- and second-order or exact welfare measures can be quite substantial when price changes are non-marginal. They point to another main difference created by the distribution of substitution elasticities, which may change the welfare effects considerably if elasticities differ over the income distribution. To account for heterogeneous preferences, we obtain own- and cross-price elasticities (e_{ij}) at the household level following Banks et al. (1997). These are then used in a cost-of-living experiment, with the second-order welfare loss approximated by a second-order Taylor series expansion of the cost function (Deaton and Muellbauer 1980b):

$$CV = \sum_{i=1}^{n} w_i \left(\frac{\Delta p_i}{p_i^0}\right) + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} w_i e_{ij} \left(\frac{\Delta p_i}{p_i^0}\right)\left(\frac{\Delta p_j}{p_j^0}\right) \qquad \text{ZEqn18 \quad (18)}$$

4.3 Household CO2 Emissions

CO2 emissions embodied in household consumption (carbon footprints) could easily be calculated with direct carbon intensities measured in available physical energy units (e.g. 2.4 kg CO2 per litre gasoline). However, the direct carbon content does not account for emissions in the production process (e.g. refining gasoline), and for electricity and the residual other goods category we would not be able to provide carbon contents. Therefore, in our analytical framework, carbon emissions are calculated from a demand-side perspective by employing an input-output (IO) model. These carbon footprints are derived by calculating the carbon intensities of the Indonesian production sectors and a subsequent matching with household consumption. The underlying database is the national IO table and CO2 emissions per industrial sector from the World Input Output Database (Timmer et al. 2015).[10] Total production emissions C_{ind} are simply a product of the matrix of sector-specific direct carbon intensities CI and total production vector x:

$$CI'x = C_{ind} \qquad\qquad \text{ZEqn19 \quad (19)}$$

Since our analysis focuses on final demand y, direct carbon intensities are not of interest and we transform equation (19) with the Leontief inverse $(I - A)^{-1}$. Recalling total production

$$x = (I - A)^{-1}y \qquad\qquad \text{ZEqn20 \quad (20)}$$

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10 The matching between WIOD sectors and the SUSENAS consumption is available upon request.

and substituting (20) for x in (19) gives us total production emissions from a demand-side perspective:

$$CI'(I - A)^{-1}y = C_{ind} \qquad \text{ZEqn21} \quad (21)$$

The multiplication of the direct carbon intensities $e'C$ by the Leontief inverse $(I - A)^{-1}$ then generates the indirect carbon intensities CI_{ind}:

$$CI_{ind} = CI'(I - A)^{-1} \qquad \text{ZEqn22} \quad (22)$$

which we use in the further analysis. For the fuels gasoline, kerosene, and LPG we have to additionally add these production-based emissions to the direct carbon content emitted in the combustion process.[11] These direct carbon contents are transformed to household-specific expenditure-based carbon intensities by calculating direct carbon emissions (quantities multiplied by carbon contents) and dividing by the respective fuel expenditures. Household-specific carbon footprints are then calculated by multiplying expenditures per good by the respective carbon intensity $CI_k(CO_2/MXN)$

$$CO_{2i} = \sum_{k=1}^{5}(exp_{ik} * CI_k) \qquad \text{ZEqn23} \quad (23)$$

After price changes take place, new expenditure levels exp_i^1 per household are derived from the simulated budget shares w_i^1 :

$$w_i^1 = \Phi\left(\widehat{\alpha_i} + \sum_{j=1}^{n}\widehat{\gamma_{ij}}\ln p_j^1 + \widehat{\beta_i}\ln\left[\frac{x^0}{a(p^1)}\right] + \frac{\widehat{\lambda_i}}{b(p^1)}\left\{\ln\left[\frac{x^0}{a(p^1)}\right]\right\}^2\right) + \varphi_i\phi + \widehat{\epsilon_i^0} \qquad \text{ZEqn24} \quad (24)$$

The carbon emissions per household are then calculated as:

$$CO_2^1 = \sum_{i=1}^{n}\left(\frac{exp_i^1}{1 + \frac{\Delta p_i}{p_i^0}} * CI_i\right) \qquad \text{ZEqn25} \quad (25)$$

where the simulated expenditures are deflated to the baseline level in period 0 to avoid upward-biased projected emission levels. Additionally, to account for consumption growth effects through redistribution via social programmes, we simulate new expenditures and the resulting carbon emissions after income changes occur.

5   Results

We simulate the welfare and energy poverty impact for two stylised scenarios (20 and 50 per cent price increase) and obtain results for single and multiple simultaneous price changes. Given the currently low international oil prices and past trends, scenarios with even higher price in-

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11 Gasoline: 2.31 kg CO2/L, Kerosene: 2.55 kg CO2/L, LPG: 1.5 kg CO2/kg.

creases of up to 100 per cent and above are indeed possible for the coming years. Yet price changes of this magnitude would require us to forecast completely out of sample. As mentioned above, the survey data offers price information for electricity, gasoline, kerosene, and LPG. Unfortunately, we do not have price information for other transport or firewood expenditures and have to exclude them from further analysis. In addition to these scenarios with energy price increases, we also simulate a scenario that interprets the price change as an ad valorem tax rate and redistributes collected tax revenues via lump-sum cash transfers to households. We assume similarity between consumers' responses to price changes due to market mechanisms and those due to taxes, although there is increasing evidence that calls this assumption into question (Rivers and Schaufele 2015; Tiezzi and Verde 2016). Since this difference is most likely to play out in the long run, our analysis still offers valid results in the short run.

5.1 Estimation Results

The first-stage estimation generates results from the probit model specification. Marginal effects, evaluated at the sample means, are displayed in Table 3. All energy-price coefficients have close to zero magnitude, which implies that energy prices appear not to be a major determinant of energy-use decisions. Income, on the other hand, is an important factor, particularly for private motorised transport. In the next step, the full demand system is estimated. Due to the difficulty of the economic interpretation of model coefficients, we report expenditure elasticities in Table 4 and price elasticities in Table 5. Following Banks et al. (1997), we calculate elasticities for each household individually and construct a weighted average, with the weights generated as the household's share of total sample expenditure for the relevant good. With rising income, the willingness to spend more on electricity increases, transforming it from a necessity to a luxury good at the 90th percentile. We observe high income responses towards gasoline use, with slightly rising budget elasticities all above one and rising over the expenditure distribution. Gasoline is clearly a luxury good for households of all incomes. Kerosene also exhibits budget elasticities close to 1, particularly for lower-income households. LPG is also estimated to be a necessity for all households, though as in the case of kerosene, the quantitative demand declines with rising income.

Households with different incomes respond quite similarly to price changes for all energy items, which is why we show only one price elasticity matrix for the first, fifth, and tenth expenditure per capita decile. In general, households react strongly to price changes for all energy items. Most own-price elasticities are close to -1, with the strongest response observed for gasoline. Based on the estimations, we expect to find differences between first- and second-order welfare effects, particularly for electricity and gasoline price changes, when high usage rates overlap with relatively large own-price elasticities. The evaluation of cross-price elasticities reveals that not all modern domestic energy items are complements. Electricity and kerosene are weak substitutes, while electricity and LPG are weak complements, more so for households with higher income. The cross-price elasticities between LPG and kerosene

are zero, which clearly shows the unimportant role of energy prices for the politically supported conversion from kerosene to LPG. Substitution between private transport in the form of gasoline demand and domestic energy has no general pattern either. Kerosene and LPG are weak substitutes and complements, respectively, for gasoline, while gasoline and electricity-gasoline cross-price elasticities are close to zero. For other countries, the substitutability of energy items appears to be very context specific, as the findings in the empirical literature demonstrate. Tiezzi and Verde (2016) find complementarity between electricity and gasoline for the United States, while Nikodinoska and Schröder (2016) find the opposite for Germany. Since this is a critical step in the further analysis, we test for the potential bias of different prices through the geographical location of the household by including province-fixed effects and find no significant difference.[12]

Table 3. First-Stage Probit Model (Marginal Effects at Means)

VARIABLES	(1) Electricity y1	(2) Gasoline y1	(3) Kerosene y1	(4) LPG y1
p1	1.23e-05***	-8.05e-06***	2.39e-05***	-4.53e-06***
	(7.67e-07)	(1.25e-06)	(1.25e-06)	(1.31e-06)
p2	-2.79e-05***	-3.23e-05***	6.73e-05***	-6.21e-05***
	(5.44e-07)	(9.96e-07)	(9.90e-07)	(1.15e-06)
p3	-2.72e-05***	-6.28e-06***	-5.01e-05***	3.20e-05***
	(2.40e-07)	(3.89e-07)	(3.88e-07)	(3.79e-07)
p4	-1.13e-05***	-4.12e-06***	2.46e-06***	-5.05e-06***
	(6.69e-08)	(7.27e-08)	(7.94e-08)	(9.61e-08)
p5	0.000723***	0.00583***	-0.0177***	0.00184***
	(6.88e-05)	(0.000113)	(0.000122)	(0.000115)
ln(x)	0.0851***	0.486***	-0.0436***	0.286***
	(0.000777)	(0.00146)	(0.00131)	(0.00131)
male	-0.0115***	0.147***	-0.0316***	-0.0158***
	(0.00120)	(0.00209)	(0.00216)	(0.00203)
age	0.000638***	-0.00385***	0.000719***	-0.000950***
	(3.05e-05)	(5.05e-05)	(5.22e-05)	(4.86e-05)
hhsize = 2	0.00387**	0.109***	0.0550***	0.107***
	(0.00178)	(0.00360)	(0.00318)	(0.00284)
hhsize = 3	0.000562	0.175***	0.0617***	0.118***
	(0.00176)	(0.00343)	(0.00312)	(0.00273)
hhsize = 4	-0.00580***	0.169***	0.0566***	0.118***
	(0.00180)	(0.00346)	(0.00316)	(0.00277)
hhsize = 5	-0.0144***	0.143***	0.0663***	0.0834***
	(0.00193)	(0.00363)	(0.00335)	(0.00294)
hhsize = 6	-0.0332***	0.0824***	0.0945***	0.0211***
	(0.00204)	(0.00375)	(0.00346)	(0.00295)
Observations	761,624	761,624	761,624	761,624

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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12 Households in remote locations face higher prices for all modern energy items and also exhibit lower demand.

Table 4. Budget Elasticities

Deciles	Electricity	Gasoline	Kerosene	LPG	Other
1	0.877	1.341	0.933	0.824	0.984
	(0.002)	(0.008)	(0.003)	(0.005)	(0.000)
2	0.890	1.391	0.905	0.810	0.984
	(0.890)	(1.391)	(0.905)	(0.810)	(0.984)
3	0.905	1.407	0.895	0.804	0.984
	(0.001)	(0.005)	(0.004)	(0.003)	(0.000)
4	0.916	1.435	0.893	0.784	0.985
	(0.001)	(0.005)	(0.004)	(0.003)	(0.000)
5	0.935	1.448	0.890	0.771	0.985
	(0.001)	(0.005)	(0.004)	(0.003)	(0.000)
6	0.950	1.446	0.886	0.754	0.985
	(0.001)	(0.005)	(0.003)	(0.003)	(0.000)
7	0.966	1.437	0.880	0.737	0.985
	(0.001)	(0.004)	(0.003)	(0.003)	(0.000)
8	0.986	1.435	0.870	0.721	0.986
	(0.001)	(0.004)	(0.003)	(0.003)	(0.000)
9	1.014	1.429	0.856	0.701	0.986
	(0.001)	(0.004)	(0.003)	(0.003)	(0.000)
10	1.083	1.361	0.780	0.623	0.988
	(0.002)	(0.004)	(0.007)	(0.003)	(0.000)

Standard errors in parentheses.

Table 5. Price Elasticities

Decile	Item	Price				
		Electricity	Gasoline	Kerosene	LPG	Other
1	Electricity	**-0.83**	0.03	0.01	-0.05	0.85
		(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
	Gasoline	0.03	**-1.01**	0.02	-0.03	0.96
		(0.001)	(0.003)	(0.001)	(0.002)	(0.003)
	Kerosene	0.03	0.05	**-0.95**	0.00	0.78
		(0.001)	(0.004)	(0.001)	(0.000)	(0.004)
	LPG	-0.10	-0.08	0.00	**-0.99**	1.20
		(0.004)	(0.005)	(0.000)	(0.001)	(0.008)
	Other	0.02	0.01	0.01	0.01	**-0.02**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
5	Electricity	**-0.82**	0.04	0.01	-0.09	0.83
		(0.001)	(0.000)	(0.000)	(0.002)	(0.001)
	Gasoline	0.03	**-1.03**	0.03	-0.08	0.97
		(0.000)	(0.002)	(0.001)	(0.002)	(0.002)
	Kerosene	0.04	0.14	**-0.95**	0.00	0.77
		(0.001)	(0.005)	(0.001)	(0.000)	(0.004)
	LPG	-0.16	-0.20	0.00	**-1.01**	1.33
		(0.002)	(0.004)	(0.000)	(0.001)	(0.006)
	Other	0.02	0.03	0.00	0.02	**-0.05**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Decile	Item	Price				
		Electricity	Gasoline	Kerosene	LPG	Other
10	Electricity	**-0.80**	0.01	0.01	-0.13	0.83
		(0.001)	(0.001)	(0.000)	(0.002)	(0.001)
	Gasoline	0.01	**-0.97**	0.04	-0.17	0.96
		(0.001)	(0.001)	(0.001)	(0.003)	(0.002)
	Kerosene	0.04	0.21	**-0.94**	0.00	0.76
		(0.000)	(0.006)	(0.001)	(0.000)	(0.004)
	LPG	-0.45	-0.75	0.00	**-1.05**	2.09
		(0.005)	(0.010)	(0.000)	(0.001)	(0.013)
	Other	0.03	0.04	0.00	0.02	**-0.05**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Standard errors in parentheses.

5.2 Welfare and Poverty Effects

A relatively moderate 20 per cent price increase for all four energy items under consideration and averaging over all households per expenditure percentile is displayed in Figure 6. As expected, electricity and gasoline make up the biggest part of the welfare losses, with a progressive pattern in both cases. The relative welfare losses for a uniform 20 per cent electricity price increase are between 0.4 and 0.6 per cent of total expenditures for the poorest and richest households, respectively. For gasoline, these relative welfare losses are larger, particularly for richer households, lying between 0.4 and 0.7 per cent. Smaller welfare effects for kerosene and LPG reflect their relatively low usage rates and budget shares. For the domestically used LPG, a price increase would be slightly regressive, but the magnitude is small due to the low usage rates. This could change, however, if more and more households begin using LPG instead of firewood – in rural areas as well. The difference between the upper-bound first-order effects and the lower-bound second-order effects is relatively small at this magnitude of price effects. First-order estimates of welfare losses in the first scenario are 10 per cent higher on average. These welfare losses become more pronounced in the second scenario of a 50 per cent price increase, where the difference increases to over 20 per cent for electricity and gasoline, again with small observed differences for kerosene and LPG (Figure 7). Particularly for gasoline, the second-order effects are slightly less progressive. Responsible for this effect is not a variation in demand responses with rising expenditures, but rather the increase in the usage rate. A larger fraction of households with actual gasoline demand also implies a larger substitution potential. Low-income households which are close to the poverty line and dependent on the use of modern energy are not as strongly represented in these average effects.

Table 6. FGT Poverty Indices (in %), Changes from Baseline (Scenarios I & II)

Price increase	Scenario	National			Rural			Urban		
		FGT (in %) – difference from baseline								
		0	1	2	0	1	2	0	1	2
Electricity	I	0.23	0.05	0.01	0.15	0.05	0.01	0.05	0.01	0.00
	II	0.51	0.10	0.03	0.43	0.10	0.03	0.10	0.03	0.00
Gasoline	I	0.21	0.03	0.01	0.16	0.03	0.01	0.04	0.01	0.00
	II	0.47	0.07	0.02	0.39	0.07	0.02	0.08	0.02	0.00
Kerosene	I	0.02	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00
	II	0.05	0.01	0.00	0.02	0.01	0.00	0.02	0.01	0.00
LPG	I	0.10	0.02	0.01	0.11	0.02	0.01	0.01	0.00	0.00
	II	0.21	0.04	0.01	0.20	0.05	0.01	0.03	0.01	0.00
Energy	I	0.59	0.11	0.03	0.49	0.11	0.03	0.11	0.03	0.00
	II	1.21	0.24	0.07	1.11	0.23	0.07	0.24	0.07	0.00

Table 7. FGT Poverty Indices (in %), Changes from Baseline (Scenarios I & II + Lump-Sum Transfer)

Price increase	Scenario	National			Rural			Urban		
		FGT (in %) – difference from baseline								
		0	1	2	0	1	2	0	1	2
Electricity	I	-0.31	-0.08	-0.02	-0.05	-0.02	-0.44	-0.03	0.00	0.00
	II	-0.60	-0.15	-0.05	-0.09	-0.03	-0.87	-0.06	0.00	0.00
Gasoline	I	-0.49	-0.12	-0.04	-0.08	-0.03	-0.67	-0.05	0.00	0.00
	II	-0.90	-0.22	-0.07	-0.15	-0.05	-1.25	-0.09	0.00	0.00
Kerosene	I	-0.05	-0.01	0.00	-0.01	0.00	-0.06	0.00	0.00	0.00
	II	-0.06	-0.01	0.00	-0.01	0.00	-0.07	0.00	0.00	0.00
LPG	I	-0.09	-0.03	-0.01	-0.01	0.00	-0.17	-0.01	0.00	0.00
	II	-0.20	-0.05	-0.02	-0.02	-0.01	-0.37	-0.03	0.00	0.00
Energy	I	-0.89	-0.21	-0.06	-0.13	-0.04	-1.28	-0.09	0.00	0.00
	II	-1.51	-0.35	-0.11	-0.22	-0.07	-2.22	-0.14	0.00	0.00

The poverty indicators in Table 6 do not show a large increase, but absolute numbers are important to consider.[13] The moderate electricity price increases in Scenario I raise the national poverty rate by 0.23 per cent, which appears to be a very small increase but means in absolute terms that approximately an additional half a million people, most of them in rural areas, will be classified as poor. For gasoline price increases, we observe a similar magnitude. Although the poverty effects are relatively small due to the low usage rates and budget shares for modern energy, a significant and growing number of households are negatively affected by price increases. Most of these households are located in urban areas, but with more rural households using modern energy items and private transport vehicles, this finding is unlikely to be stable over time. Non-negligible effects can also be found for LPG price increases, which demonstrates LPG's importance as the new major cooking fuel for Indonesian households.

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13 Second-order welfare effects are used in the computation of post-reform poverty indices.

In the multiple price change scenario, changing prices for all four energy items simultaneously, we observe a general progressive pattern, dominated by electricity and, in particular, gasoline (Figure 8). Nevertheless, multiple price changes for the energy items under consideration would result in serious welfare losses for poor households of close to 1.5 and 3 per cent of total expenditures in the case of Scenario I and Scenario II, respectively. Particularly in the case of Scenario II, higher usage rates and associated substitution options for higher-income households make the distributional effect less progressive. On the other hand, this lower progressivity also means there is less need to redistribute tax revenue to higher-income households, since they are capable of dealing with price increases. The poverty effects are quite strong, with increases of 0.6 and 1.2 percentage points in the poverty rate for Scenario I and Scenario II, respectively.

To shed some light on the potential effects of redistribution if energy taxes of 20 per cent are the drivers behind the price increases, we simulate a full redistribution of tax revenues via lump-sum transfers to households. For all four energy items, the redistribution of tax revenue leads to welfare gains for low-income households (Figure 9). Electricity and gasoline taxes raise substantial revenue, which could lead to quite large welfare gains for the majority of the population if proper redistribution schemes can be identified. Welfare gains are also reflected in the poverty indicators, which improve for all scenarios (Table 7). As much as urban households are disproportionately hit by energy price hikes, there are also more urban households which benefit from transfer payments. Since universal lump-sum transfers are unlikely to be implemented, more realistic redistribution schemes would rely on social welfare programmes, which directly target the poor.[14]

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14 The survey data does offer information on social welfare programmes, but unfortunately their coverage is limited and therefore unsuitable for a large-scale redistribution scheme.
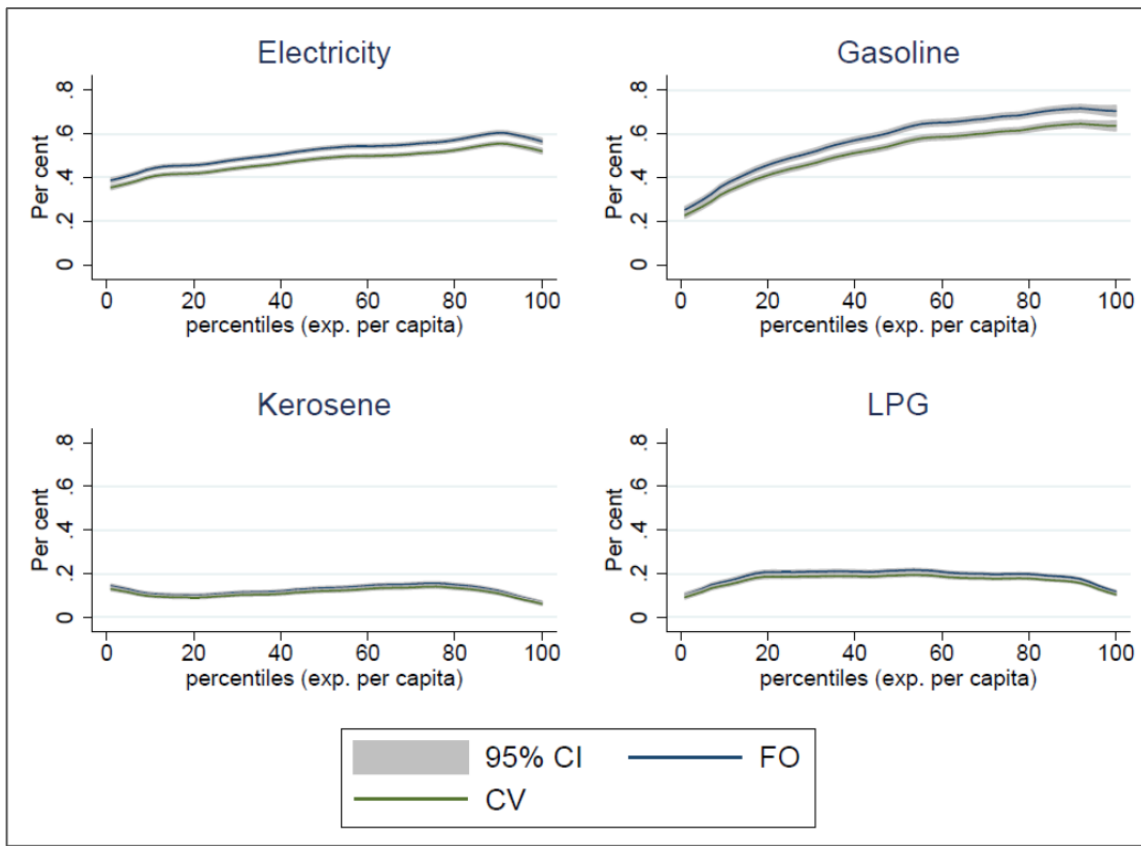
Figure 6. Welfare Effects, Scenario I

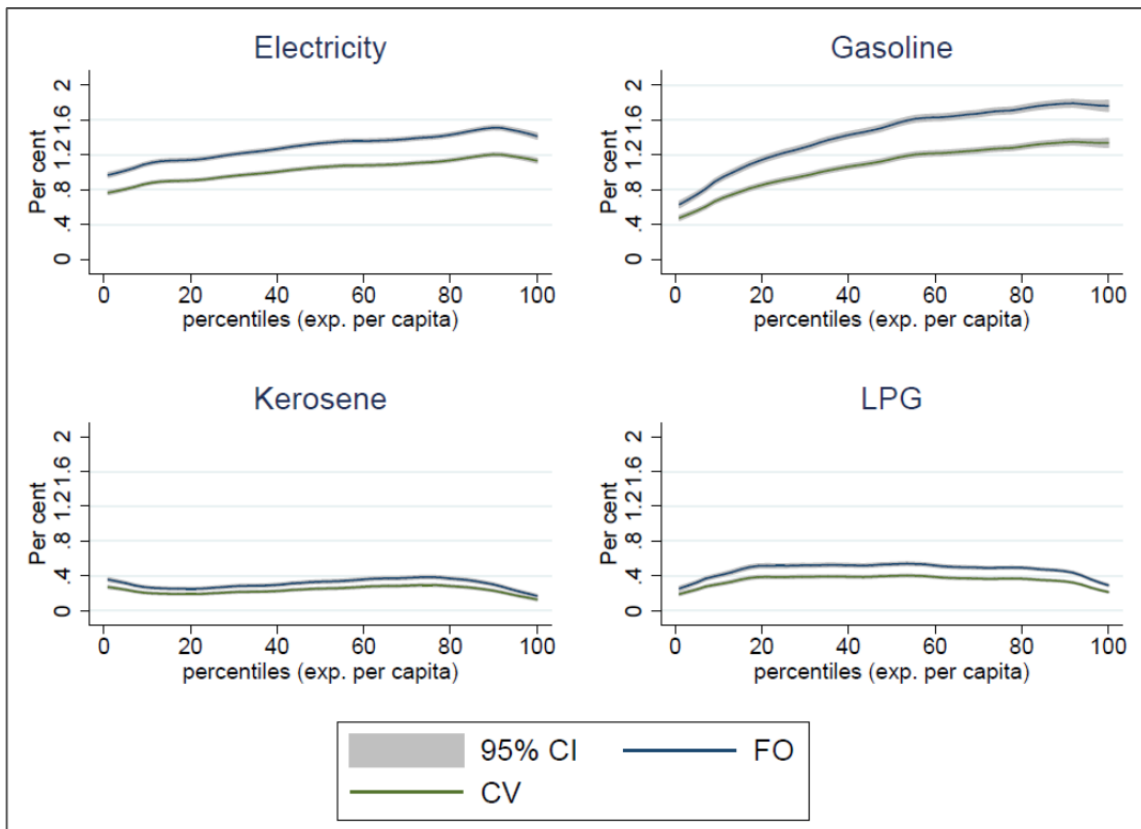**Figure 7. Welfare Effects, Scenario II**

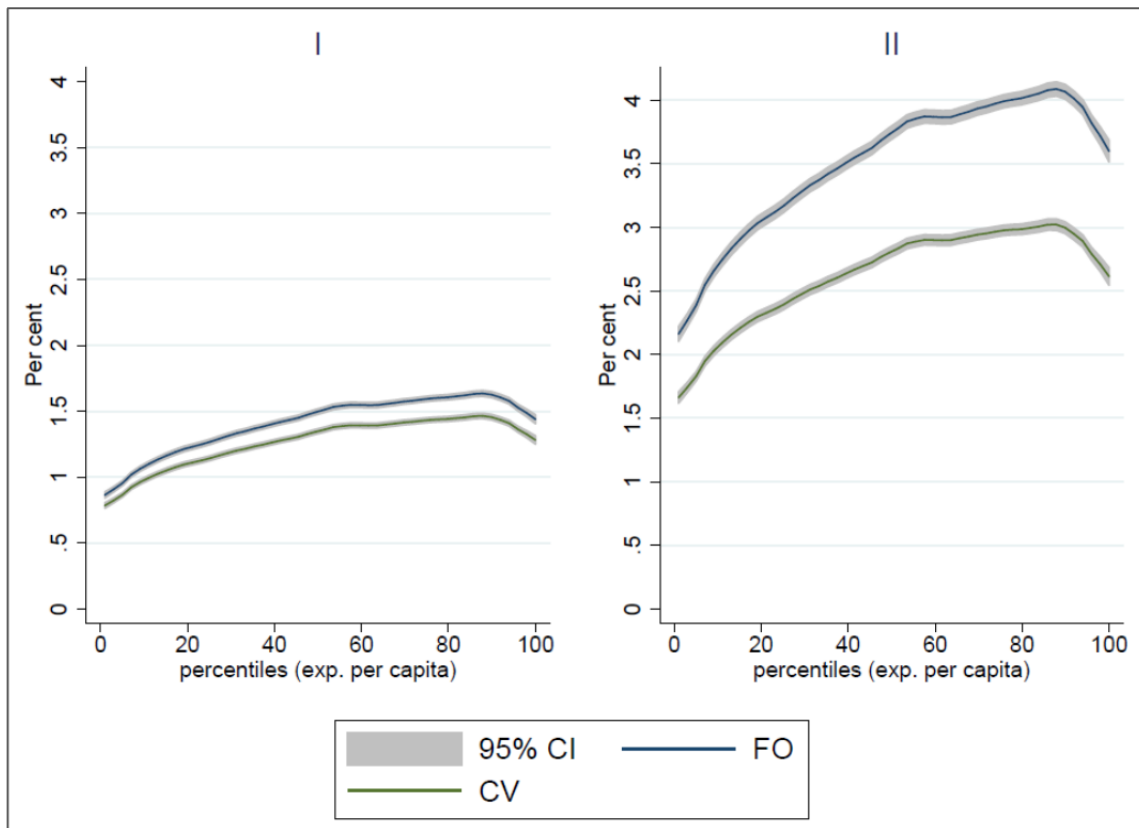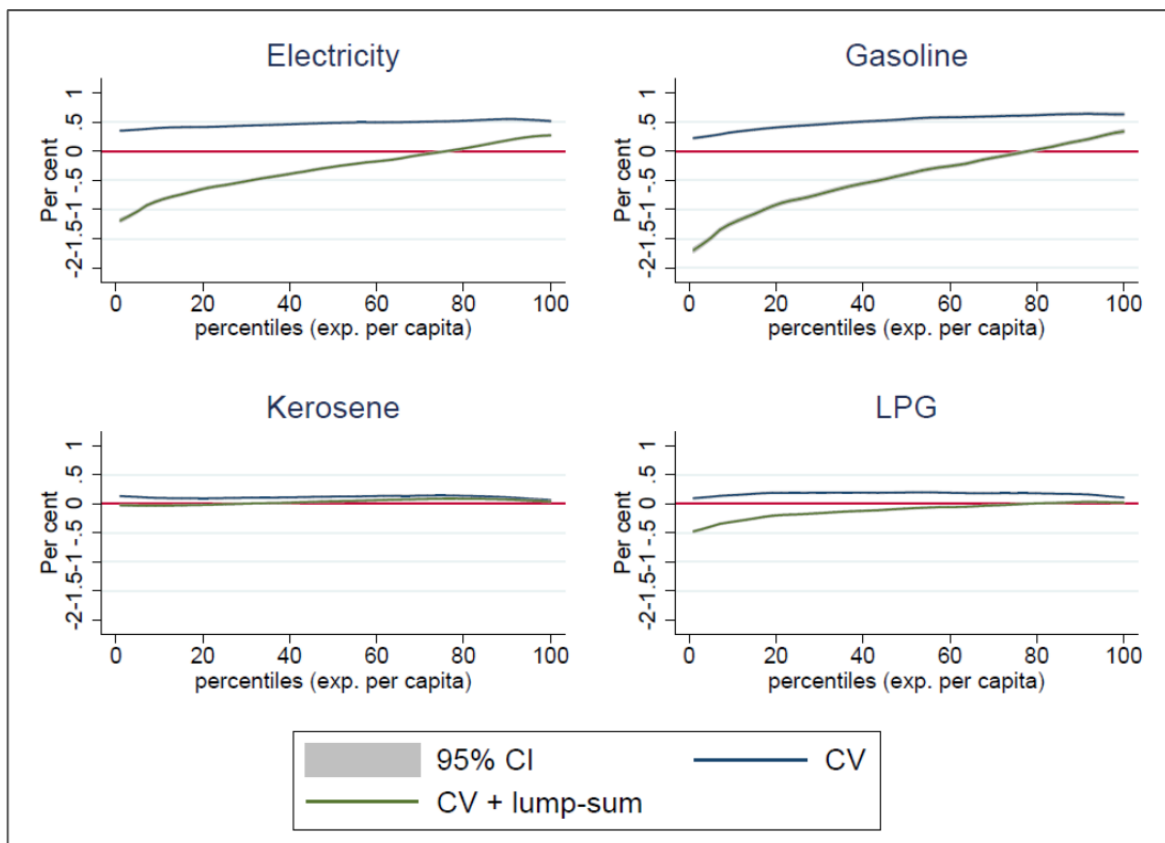**Figure 8. Welfare Effects Simultaneous Increase, Scenarios I & II**

Figure 9. Welfare Effects with Lump-Sum Transfers, Scenario I

5.3 Energy Poverty

Based on the estimated price elasticity matrices, we calculate the quantities households reduce per capita in response to price increases for the respective scenarios. Based on these behavioural responses, we calculate the FGT class of indices for both scenarios and energy poverty lines and find significant effects on energy poverty resulting from lower energy use. Table 8 displays the change in FGT indicators for the two simulated scenarios. We find that price increases have considerable effects on the poverty rate, with particularly tremendous effects in the case of electricity and LPG price increases. LPG price increases result in higher energy poverty levels than kerosene price increases, with the latter demonstrating the smallest effects, as expected. For all modern fuels, the increase in energy poverty is greater in rural areas, despite the higher urban usage rates. As discussed in the interpretation of estimated price elasticities, complementarity between LPG and gasoline implies reduced domestic energy use, also in the case of gasoline price increases. Energy poverty increases due to gasoline price changes are approximately 25 per cent of those resulting from LPG price increases, a value close to the estimated cross-price elasticity. The redistribution of tax revenues does not significantly change energy poverty since households are projected to spend most of the extra income on goods other than energy.[15] These findings reflect the downside of consumer responses and the associated smaller welfare effects through substitution. While the microeconomic welfare metric tells us only about utility-based monetary effects, other welfare dimensions such as energy poverty are not directly addressed in a standard welfare assessment. Although one could argue that households take energy requirements into account in consumption decisions, they are also likely to substitute traditional fuels for modern fuels when prices rise. Additionally, they may not internalise all associated external costs such as health issues caused by air pollution. Unfortunately, our data does not permit us to quantify the exact nature of substitution between modern and traditional fuels when prices change. However, a simple estimation of firewood demand in a Working-Leser form (Leser 1963; Working 1943) depending on prices for modern energy sources, household total expenditures x, and household characteristics H sheds some light on this issue:

$$w_{fwd} = \alpha_{fwd} + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + ln(x) + H \qquad\qquad \text{ZEqn26} \quad (26)$$

Due to a significant share of zero firewood budget shares, equation (26) is estimated as a Heckman selection model with additional variables reflecting lighting and cooking fuel choice in the identifying equation.[16] The estimated firewood cross-price elasticities (Table 10) exhibit an expected substitutability between the other domestically used energy items – elec-

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15 The results are almost identical to the scenario without redistribution and therefore not reported.

16 As in the case of demand system coefficients, we do not report results due to the difficulty of the economic interpretation. We report elasticities instead.

tricity, kerosene, and LPG – and firewood. This provides some evidence – though it is not integrated into the rest of the analysis due to data constraints – that households are very likely to increase the use of traditional fuels when prices of modern, domestically used energy items rise. Households may not reduce domestically used energy as strongly as energy poverty indices suggest, but instead move towards traditional fuels.

Table 8. FGT Energy Poverty Indices (in %), Changes from Baseline (Scenario I)

		National			Rural			Urban		
		FGT (in %) – difference from baseline								
Price increase	Energy poverty line	0	1	2	0	1	2	0	1	2
Electricity	EPL 1	4.27	2.87	2.09	3.07	2.86	2.37	5.87	2.89	1.72
	EPL 2	2.84	1.49	0.95	3.33	1.99	1.32	2.19	0.84	0.47
Gasoline	EPL 1	1.03	0.40	0.13	0.41	0.08	-0.10	1.85	0.83	0.43
	EPL 2	0.20	-0.10	-0.14	-0.07	-0.26	-0.27	0.55	0.11	0.03
Kerosene	EPL 1	0.88	0.69	0.58	0.97	0.97	0.89	0.76	0.32	0.17
	EPL 2	0.74	0.51	0.37	1.19	0.85	0.63	0.13	0.06	0.02
LPG	EPL 1	3.77	2.37	1.61	2.70	2.22	1.71	5.18	2.57	1.48
	EPL 2	2.11	0.99	0.62	2.32	1.26	0.85	1.84	0.62	0.32

Table 9. FGT Energy Poverty Indices (in %), Changes from Baseline (Scenario II)

		National			Rural			Urban		
		FGT (in %) – difference from baseline								
Price increase	Energy poverty line	0	1	2	0	1	2	0	1	2
Electricity	EPL 1	4.05	2.67	1.93	2.83	2.63	2.17	5.65	2.72	1.61
	EPL 2	2.61	1.36	0.86	3.03	1.80	1.19	2.05	0.78	0.43
Gasoline	EPL 1	0.73	0.15	-0.07	0.15	-0.22	-0.35	1.50	0.64	0.31
	EPL 2	-0.05	-0.26	-0.24	-0.38	-0.49	-0.42	0.39	0.05	0.00
Kerosene	EPL 1	0.84	0.67	0.56	0.94	0.94	0.87	0.72	0.30	0.16
	EPL 2	0.70	0.50	0.36	1.14	0.84	0.62	0.11	0.05	0.02
LPG	EPL 1	3.66	2.30	1.55	2.61	2.13	1.64	5.06	2.51	1.44
	EPL 2	2.05	0.94	0.59	2.24	1.20	0.80	1.80	0.60	0.31

Table 10. Firewood Cross-Price Elasticities

	Prices			
	Electricity	Gasoline	Kerosene	LPG
Firewood	0.11	-2.29	0.41	0.28

5.4 CO2 Emission Effects

Since households respond to price changes, the effect on household-related carbon emissions is expected to be negative with the estimated price elasticities. How large this effect is for the single energy items can be seen in Table 11. The elasticity of household carbon emissions relative to price changes is the highest for electricity and gasoline due to the high carbon inten-

sity of electricity and high budget shares for gasoline. Moderate price changes of 20 per cent for electricity and gasoline lead to already substantial emission reductions on the order of 4.7 and 5.4 per cent of household carbon emissions. Redistribution of tax revenues does not change this picture tremendously, with 10 per cent lower reductions on average, although absolute reductions will decline with the size of the price change and redistributive transfers. Although these emission reductions appear to be rather large, they have to be put into perspective. They cannot be readily compared to domestic, production-based emissions, which are approximately 25 per cent greater than demand-side emissions.[17] Household emissions in turn make up only 65 per cent of demand-side emissions, which include imported emissions under the domestic technology assumption.[18] Relative to total production CO2 emissions, households are responsible for approximately 50 per cent. Additionally, the household survey covers only about 50 per cent of demand emissions calculated with the IO data. How to ultimately interpret the emission reductions is a question of determining how to deal with the large disparity between the survey and IO data. If the survey data is scaled up to match the total aggregate consumption in the IO tables, the calculated relative reductions of household emissions remain identical. Relative to total domestic, production-based CO2 emissions, the estimated reductions need to be adjusted downwards by 50 per cent if the survey data is scaled or 75 per cent when it remains unscaled.

Table 11. Household CO2-Price Elasticities

Scenario	Electricity	Gasoline	Kerosene	LPG	Energy
Price increase	-0.238	-0.272	0.022	-0.141	-0.612
Price increase + lump_sum	-0.214	-0.243	0.024	-0.133	-0.555

6 Conclusion

Consumer energy price increases affect richer households more in relative terms, and therefore also in absolute terms. On the one hand, our findings confirm prior studies, which are based on observed demand and the assumption of zero substitution between goods, on the progressive direction of this effect for electricity and gasoline. On the other hand, we find neutral effects for kerosene and LPG and smaller welfare losses for electricity and gasoline by employing second-order welfare estimates. The calculated first-order effects for electricity and gasoline are on average 10 and 20 per cent larger in Scenario I and Scenario II, which may seem small in relative terms but represent substantial differences in absolute terms. First-order effects particularly overestimate welfare losses for the upper part of the income

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[17] Domestic demand emissions (including imports) make up only 80 per cent of domestic production emissions; the rest of the emissions are exported.

[18] Demand-side emissions include expenditures from households, government, and gross fixed capital formation, and changes in inventories and valuables.

distribution, where small percentage changes in relative terms translate into large absolute monetary amounts. This has important consequences for redistribution, since richer households are estimated to be capable of dealing with increasing energy prices and therefore less in need of compensation. This holds particularly for gasoline, which is at the centre of the subsidy debate and a major fuel used by households. Due to low-income households' lower usage rates, the poverty impacts are also moderate when prices change by small amounts.

Despite these supposedly small relative changes, a non-marginal number of low-income households are actually highly affected by energy price changes. Additionally, a substantial and growing number of households are vulnerable to large energy price increases, which may be quite likely when energy subsidies are completely abolished. Ultimately, the redistribution of taxes or saved subsidies is crucial to turning this story around to create welfare gains and poverty reduction. Although the simulated lump-sum transfers are quite effective in absorbing large welfare shocks, more targeted transfers are certainly desirable from an equity and fiscal perspective. The estimation of a demand system proves to be useful for calculating welfare effects, and the consideration of energy poverty and household-related carbon emissions makes it even more valuable. Without changes in the quantities demanded being taking into account, the degree of energy poverty would not change in our expenditure-based definition of energy poverty. In addition to welfare losses from energy price increases, households also suffer from a lack of modern energy items, which could trigger additional negative impacts such as adverse health effects through the shift to traditional sources of energy. By simulating energy item quantities, we find that price increases for energy used domestically have substantial effects on energy poverty. Somewhat surprisingly, this also holds for gasoline, since the estimation reveals a complementary relationship to LPG. This complementarity is particularly problematic for low-income households, for which these energy goods have much more of a necessity character than they do in high-income households. The resulting divergence of relatively small estimated second-order welfare effects and large impacts on energy poverty reflects a weakness of standard welfare metrics, which assumes complete information and the absence of negative externalities.

Additionally, the redistribution of tax revenue is only partially able to deal with rising energy poverty in our model since households spend most of the transfer income on goods other than modern energy. The resulting increased use of traditional biomass fuels such as firewood is certainly critical from both a health perspective, due to indoor air pollution, and a CO2 emission perspective, due to deforestation. The reduction of carbon emissions embodied in household consumption is the flip side of the coin for energy poverty increases and welfare losses. The pricing of direct energy use by households leads to substantial emissions reductions on the order of 0.28 per cent for each per cent increase in prices for gasoline or electricity. Analog to the results for energy poverty, where households only partially increase their energy use due to redistributive transfers, the adverse emission effect of redistribution is very limited, with 10 per cent smaller reductions. These emission reductions are, in ac-

cordance with the nature of our data and model, exclusively embodied in household consumption. When compared to production-based CO_2 emissions, which are usually referred to in other studies, the effects are approximately half of what is estimated. For all simulated effects, we have to keep in mind that households can only reduce energy use to a certain minimum level. This and the nature of our modelling framework restricts the interpretation of results to the very short-run perspective.

Bibliography

Ahmad, E., and Stern, N. (1984). The Theory of Reform and Indian Indirect Taxes. *Journal of Public Economics*, 25(3):259–298.

Angelou, N., Elizondo Azuela, G., Portale, E., Jaques Goldenberg, I., Bhatia, M., Banerjee, S. G., Bushueva, I., Inon, J. G., and Sarkar, A. (2013). *Global Tracking Framework*. Technical Report 77889, The World Bank.

Arze del Granado, F. J., Coady, D., and Gillingham, R. (2012). The Unequal Benefits of Fuel Subsidies: A Review of Evidence for Developing Countries. *World Development*, 40(11): 2234–2248.

Banks, J., Blundell, R., and Lewbel, A. (1996). Tax Reform and Welfare Measurement: Do We Need Demand System Estimation? *The Economic Journal*, 106(438):1227–1241.

Banks, J., Blundell, R., and Lewbel, A. (1997). Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics*, 79(4):527–539.

Chen, Z., and Yen, S. T. (2005). On bias Correction in the Multivariate Sample-Selection Model. *Applied Economics*, 37(21):2459–2468.

Clements, M. B. J., Coady, D., Fabrizio, M. S., Gupta, M. S., Alleyne, M. T.S. C., and Sdralevich, M. C. A. (2013). *Energy Subsidy Reform: Lessons and Implications*. International Monetary Fund.

Dartanto, T. (2013). Reducing Fuel Subsidies and the Implication on Fiscal Balance and Poverty in Indonesia: A Simulation Analysis. *Energy Policy*, 58:117–134.

Deaton, A. (1988). Quality, Quantity, and Spatial Variation of Price. *The American Economic Review*, 78(3):418–430.

Deaton, A., and Muellbauer, J. (1980a). An Almost Ideal Demand System. *The American Economic Review*, 70(3):312–326.

Deaton, A., and Muellbauer, J. (1980b). *Economics and Consumer Behavior*. Cambridge University Press.

Durand-Lasserve, O., Campagnolo, L., Chateau, J., and Dellink, R. (2015). *Modelling of Distributional Impacts of Energy Subsidy Reforms*. OECD Environment Working Papers, Organisation for Economic Co-operation and Development, Paris.

Ecker, O., and Qaim, M. (2011). Analyzing Nutritional Impacts of Policies: An Empirical Study for Malawi. *World Development*, 39(3):412–428.

Fan, J., and Gijbels, I. (1996). *Local Polynomial Modelling and Its Applications: Monographs on Statistics and Applied Probability 66*. CRC Press.

Feldstein, M. S. (1972). Distributional Equity and the Optimal Structure of Public Prices. *The American Economic Review*, 62(1/2):32–36.

Foster, V., Tre, Jean-Philippe, and Wodon, Quentin (2000). *Energy Prices, Energy Efficiency, and Fuel Poverty*. Technical report, World Bank.

Gundimeda, H., and Khlin, G. (2008). Fuel Demand Elasticities for Energy and Environmental Policies: Indian Sample Survey Evidence. *Energy Economics*, 30(2):517–546.

Heckman, J. J. (1979). Sample Selection Bias as a Specification Error. *Econometrica*, 47(1):153–161.

Heien, D., and Wessells, C. R. (1990). Demand Systems Estimation with Microdata: A Censored Regression Approach. *Journal of Business & Economic Statistics*, 8(3):365–371.

Hicks, J. (1939). *Value and Capital*. Clarendon Press, Oxford.

IEA (2014). *World Energy Outlook 2014*. Organisation for Economic Co-operation and Development, Paris.

Labandeira, X., Labeaga, J. M., and Rodrguez, M. (2006). A Residential Energy Demand System for Spain. *Energy Journal*, 27(2):87–111.

Leser, C. E. V. (1963). Forms of Engel Functions. *Econometrica*, 31(4):694–703.

Lewbel, A., and Pendakur, K. (2009). Tricks with Hicks: The EASI Demand System. *American Economic Review*, 99(3):827–63.

MEMR (2014). *Handbook of Energy & Economic Statistics of Indonesia 2014*. Ministry of Energy and Mineral Resources, Jakarta.

Modi, Vijay, Lallement, Dominique, and Saghir, Jamal (2005). *Energy Services for the Millennium Development Goals*. Technical report,

Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project, and World Bank, New York.

Nikodinoska, D., and Schröder, C. (2016). On the Emissions Inequality and Emissions Welfare Trade-offs in Energy Taxation: Evidence on the German Car Fuels Tax. *Resource and Energy Economics*, 44:206–233.

Olivia, S., and Gibson, J. (2008). Household Energy Demand and the Equity and Efficiency Aspects of Subsidy Reform in Indonesia. *The Energy Journal*, 29(1):21–39.

Pitt, M. M. (1985). Equity, Externalities and Energy Subsidies: The Case of Kerosene in Indonesia. *Journal of Development Economics*, 17(3):201–217.

Rivers, N., and Schaufele, B. (2015). Salience of Carbon Taxes in the Gasoline Market. *Journal of Environmental Economics and Management*, 74:23–36.

Shah, A., and Larsen, B. (1992). *Carbon Taxes, the Greenhouse Effect, and Developing Countries*. Policy Research Working Paper Series 957, The World Bank.

Shah, A., and Whalley, J. (1991). Tax Incidence Analysis of Developing Countries: An Alternative View. *The World Bank Economic Review*, 5(3):535–552.

Shonkwiler, J. S., and Yen, S. T. (1999). Two-Step Estimation of a Censored System of Equations. *American Journal of Agricultural Economics*, 81(4):972–982.

Stern, N. (1987). The Theory of Optimal Commodity and Income Taxation. In: *The Theory of Taxation for Developing Countries*. Oxford University Press.

Sterner, T. (ed.) (2011). Fuel Taxes and the Poor: The Distributional Effects of Gasoline Taxation and their Implications for Climate Policy. *RFF Press*, New York.

Tiezzi, S., and Verde, S. F. (2016). Differential Demand Response to Gasoline Taxes and Gasoline Prices in the U.S. *Resource and Energy Economics*, 44:71–91.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., and de Vries, G. J.(2015). An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production. *Review of International Economics*, 23(3):575–605.

West, S. E., and Williams III, R. C. (2004). Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes. *Journal of Environmental Economics and Management*, 47(3):535–558.

Working, H. (1943). Statistical Laws of Family Expenditure. *Journal of the American Statistical Association*, 38(221):43–56.

World Bank (2013). Indonesia Economic Quarterly. *Indonesia Economic Quarterly*. World Bank Indonesia, Jakarta.

Yen, S. T., Kan, K., and Su, S.-J. (2002). Household Demand for Fats and Oils: Two-Step Estimation of a Censored Demand System. *Applied Economics*, 34(14):1799–1806.

Yusuf, A. A. and Resosudarmo, B. P. (2008). Mitigating Distributional Impact of Fuel Pricing Reform: The Indonesian Experience. *ASEAN Economic Bulletin*, 25(1):32–47.

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