Redistribution with Limited Information: Fuel Subsidies and Cash Transfers in Indonesia*

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Abstract

In-kind transfers may outperform cash as a means of progressive redistribution when a government has limited data with which to identify poor households. We formulate a model of redistribution with limited information to examine the grounds for one of the most common types of in-kind transfers worldwide: energy subsidies. In our model, a planner with progressive redistributional goals and limited information chooses between cash transfers and nonlinear fuel subsidies. The optimality of a nonlinear fuel subsidy over a targeted cash transfer is determined by the joint distribution of household income, observable characteristics, and household fuel demand. We estimate the primitives of this model for the Indonesian population using rich administrative survey data and variation generated by large fuel policy reforms. We quantify optimal interventions among nonlinear fuel prices, targeted cash transfers, and combinations of the two. Combinations of cash and in-kind programs, involving self-financing fuel pricing policies, outperform single interventions.

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1 Introduction

Energy subsidies are a mainstay of public policy in many developing countries, and one of the most popular types of in-kind transfers worldwide (Burlig and Sudarshan, 2025; Coady et al., 2017; IEA, n.d.). They amounted to 6.2% of GDP in Indonesia in 2022, and 1.3% globally (Black et al., 2023).[1] They appeal as a mode of redistribution in developing settings by overcoming a key challenge — namely that governments in these economies often don't observe household income or wealth, which are used in alternative transfer systems like cash payments or income taxation[2]. Yet, energy subsidies are usually not progressive. Because wealthier households consume more fuel, they capture a large share of subsidy spending (del Granado et al., 2010). Subsidy reform is therefore a common policy priority (World Bank, 2022). Standard economic models and policy institutions alike recommend replacing subsidies with cash transfer programs targeted to low income households (Atkinson and Stiglitz, 1976; Strand, 2016), but limited information about household income threatens governments' abilities to identify these households and assign cash. When information is limited, nonlinear fuel subsidies can outperform targeted cash transfers by inducing self-selection (Akbarpour et al., 2024, henceforth ADK).

We explore two approaches to fuel subsidy reform: (1) a cash approach of phasing out fuel subsidies and reallocating this spending towards a targeted cash transfer; and (2) an in-kind approach of moving from a linear fuel price schedule to a nonlinear one. Under the cash approach, the government uses observable household characteristics like the material of a house's roof to predict unobserved household income, and makes a transfer to all households below a predicted income threshold. Under the in-kind approach, the government reduces subsidy spending by implementing a nonlinear price – initial units of fuel are more heavily subsidized than subsequent units. This approach may be well-targeted: low-income households consuming less fuel face the low price for most of their consumption, while large quantities of fuel are charged a high price. The preferred policy depends on the information a government has about its households, unobserved household characteristics, and households' consumption patterns over fuel (ADK; Kang and Watt, 2024). We evaluate the preferred approach for a planner with a progressive redistributional goal and characterize how the optimal policy depends on these three factors by bringing new theory to data for the first time.

The Indonesian fuel subsidy reform of 2005 provides an ideal empirical setting due to policy variation and rich administrative household survey data. The government sharply reduced fuel subsidies in 2005, resulting in an 88% price hike for the 23% of Indonesian households using gasoline for transportation and a 186% price hike for the 90% of households using kerosene for cooking. At the same time, it implemented the Bantuan Langsung Tunai (BLT) targeted cash transfer program, which aimed to assign large (15% of monthly expenditure for the average recipient) cash transfers

[1]These values are before accounting for additional "implicit" subsidization of energy relative to its full social marginal cost, that is, accounting for externalities associated with their consumption.

[2]Energy subsidies are motivated by other goals in developing countries, such as stimulating economic growth, reducing inflation, and overcoming political economic constraints

to the poorest 30% of households. Its success ran up against the crucial information friction present in this setting, namely that household income and total per capita consumption are unobserved for most households. Cash was assigned based on observable proxies instead, which diluted the progressiveness of the transfer – only 46% of the targeted group received the transfer (World Bank, 2006).

As both a theoretical framework and the core of our empirical analysis, we model the policy design decision of a government with a progressive distributional goal who considers cash and in-kind subsidy mechanisms and observes limited information about households, building on ADK, Kang (2020), and Pai and Strack (2022). When the planner is highly informed about households in her population, observing their income or wealth, she always prefers to redistribute via cash transfers. When information is limited – for example, if she could observe a proxy of income but not income itself – she may maximize surplus by intervening in the market for an important consumption good. This occurs because households' consumption choices in the face of a nonlinear fuel price may generate useful self selection – low income households' entire fuel expenses are subject to heavy subsidy, while high incomes households who consumer more fuel must pay higher prices for additional units of fuel. Crucially, the optimality of an in-kind mechanism over a targeted cash transfer is determined not only by the household characteristics observed for targeting, but rather by the relationship between these characteristics and fuel demand.

Our methodological contribution lies in making the first attempt at bringing this model to data, which requires mapping an abstract household type space onto a set of estimable parameters, relaxing structure on household preferences for realism, and extending the model to incorporate vertical structure in supply. In the model, the policy-maker observes the joint distribution of (1) household income, (2) preferences over household fuel consumption, and (3) household observable characteristics (the information set), choosing a policy to maximize social welfare. Welfare is weighted to capture the planner's preferences for progressive redistribution. Our main empirical task, then, is to estimate this joint distribution. We directly observe from the data both (1) household income and (3) household observable characteristics in our nationally-representative households survey. The remaining task to complete the full joint distribution is to specify and estimate household preferences, or demand, over fuel as a function of household characteristics.

We model fuel demand as a flexible log-log function of fuel price and household income. We estimate heterogeneous price elasticities by terciles of the income distribution to allow for different price sensitivities across income groups. Our first finding is that willingness to pay for fuel is increasing in household income, suggesting a role for targeting via the in-kind mechanism. In the kerosene market for cooking fuel low income consumers are more price sensitive than are high income consumers. Price sensitivity among households consuming gasoline increases with income.

With all model parameters in hand, we turn to the central research question: How does the optimal progressive fuel subsidy compare with a targeted cash transfer? Using our estimates of household preferences, as well as an intranational fuel supply model, we solve the planner problem of our theoretical model. For a given information set and policy budget, we compare total welfare under the optimal nonlinear fuel subsidy with total welfare under a cash transfer of the same budget. We do this in two steps. In the first, we compute the optimal nonlinear fuel subsidy. The optimal fuel subsidy is the one that maximizes the sum of weighted household utility. We search for this subsidy program within the class of two-part tariffs (excluding fuel subsidy policies that include lump sum payments to households[3]), restricting policies to this class for real-world implementability and computational tractability. While our specified Marshallian demand function corresponds to a standard indirect utility function under linear prices, we seek to evaluate welfare under our nonlinear counterfactual prices. We do this by taking the Hicksian approach developed by Reiss and White (2006) and You and Lim (2017), measuring the exact welfare effects of reforms using equivalent variation.[4] In the second step, we compare the equivalent variation associated with fuel subsidy reform with that of targeted cash transfers, weighted by the planner's distributional preferences. We quantify both the welfare gain generated by each policy and the policy budgets relative to welfare and spending in 2006.

This yields an initial set of comparisons across cash and fuel subsidy approaches. We compare the 2005 BLT cash transfer program against counterfactual nonlinear fuel pricing policies of the same budget. We find that the welfare gain associated with introducing the 2005 BLT cash transfer program is 2.83 (kerosene) and 3.77 (gasoline) times greater than that of a budget-equivalent counterfactual nonlinear fuel price, using 2006 prices as a baseline. Even a budget equivalent *un*-targeted transfer divided equally across all households in the population outperforms a nonlinear fuel subsidy, producing 195-260% of the welfare gain generated by the optimal in-kind approach. The large program budget erodes the potential of the nonlinear fuel subsidy: the optimal fuel pricing scheme offers 18 liters of fuel at price 200 Indonesian Rupiah (IDR)/liter and subsequent units at price 1639 IDR/liter, leaving fuel heavily subsidized for all consumers. The ranking of policies is unaffected by incorporating the welfare costs of climate damages generated by introducing each policy.

Since large program budgets yield cheap fuel for all consumers, we next we explore smaller reforms. Under smaller programs, the case for nonlinear subsidies over cash transfers arises. We document welfare under each policy for a range of program budgets, from $\frac{1}{6}^{\text{th}}$ of the BLT budget up to the full program budget. At $\frac{1}{6}^{\text{th}}$ of the BLT budget (200 billion IDR), the nonlinear kerosene subsidy generates 1.2 times the welfare gain generated by the cash transfer. The transfer associated with the nonlinear subsidy is well-targeted: 6 units of fuel are available at 201 IDR/liter, and additional units cost 3109 IDR/liter under the optimal nonlinear price. As the budget increases, the cash transfer quickly becomes the preferred policy once total spending reaches 250 billion IDR.

[3]Unless explicitly stated, nonlinear fuel subsidies in this paper do not include lump sum payments. See Section 2.4 for detailed discussion.

[4]Equivalent variation is the amount of income needed to make a household indifferent between the new policy and the status quo. It is computed as the difference between the total expenditure required at the status quo price regime to achieve the level of utility under the new policy, and total expenditure under the status status quo (prices and utility level).

A nonlinear gasoline subsidy is inferior to targeted cash at all budgets. Since few low-income households consume gasoline, the government cannot generate a progressive subsidy that reaches these households.

Because both targeted cash and nonlinear kerosene pricing generate welfare gains, we next explore whether a combined intervention may be optimal. Under our theoretical model, when preferences over fuel consumption contain *additional* information about households beyond that contained in observable household characteristics, the planner will combine both approaches. In our next set of analyses, we explore whether the planner would prefer to split the policy budget across both fuel subsidies and cash transfers in our setting. We assume in this exercise that the fuel policy cannot be used to generate additional revenue for the cash budget. We modify the planner problem to model this decision, solving jointly for the optimal budget share allocated towards each of the cash transfer and fuel subsidy, as well as for the optimal nonlinear fuel subsidy scheme given the coincidental cash transfer. This yields a key result. Relative to the 2006 baseline, the government can introduce a budget-neutral nonlinear kerosene policy by subsidizing a small number of units relative to its 2006 price, and marking up additional units. This generates progressive redistribution and increases aggregate welfare without any additional spending. Indeed, the optimal joint policy involves allocating the full policy budget towards the cash transfer, while simultaneously introducing this budget-neutral nonlinear kerosene subsidy. This joint policy generates 1.64 times the welfare gain of the budget-equivalent nonlinear kerosene subsidy, and 1.96 times the welfare gain of the budget-equivalent targeted cash transfer. Under the optimal policy, all spending is allocated to the cash transfer – diverting any of the joint policy budget away from cash and into the fuel subsidy reduces welfare.

While our study of fuel policy focuses on subsidization, our results suggest that fuel taxation may generate further welfare gains by raising revenue to fund larger targeted cash transfers. In the gasoline market in particular, where high-income households dominate the market, nonlinear fuel pricing may be a component of optimal policy if it involves taxation. We extend our counterfactual exercises to explore prices above international market prices. Indeed, allowing for taxation generates policies that outperform all others. When prices under the second tier of the nonlinear tariff feature a 50% tax, and fuel tax revenue is added to the cash transfer budget, the welfare gain is over 2 (gasoline) to 3 (kerosene) times larger than the pure targeted cash transfer.

Finally, we ask how the set of household observables available to the Indonesian government in 2005 shapes the ranking across policies. The BLT cash transfers were assigned to households on the basis of a set of targeting observables like housing characteristics and household head demographics, which are typical of many targeted cash transfer programs worldwide (Hanna and Olken, 2018). We compare the BLT cash transfer and nonlinear fuel subsidies to cash transfers using two alternative information sets. The first is a limited information set featuring just two dwelling characteristics – house ownership and house floor area. The second is a village-level targeting approach where transfers are assigned at the village level on the basis of village mean per capita household consumption. The village approach represents an alternative information set, forgoing observables from the BLT targeting census in favor of nationally-representative consumption survey data. At a policy budget of 200 billion IDR, the village level transfer outperforms the BLT program and generates nearly as large a welfare gain as nonlinear kerosene pricing, while the limited information set transfer generates 77% as large a welfare gain as the BLT program. Even with such a heavily restricted targeting information set, this transfer generates over 2 times the welfare gain of the nonlinear gasoline policy.

Related Literature

Our main contribution is to quantify the role of the government information set in determining optimal redistributional policy. Theory developing the case for in-kind mechanisms for a planner with distributional preferences dates back to, e.g., Weitzman (1977) and Nichols and Zeckhauser (1982). Recent work in mechanism design develops optimal redistribution schemes for planners regulating a goods market and imperfectly observing household types (Dworczak et al., 2021, ADK, Kang, 2020, Kang and Watt, 2024). We are the first to take this rich information and preference structure to the data. Our approach departs from standard models of redistribution via income and commodity taxation in two ways. First, income taxation is unavailable in our setting due to the high degree of informality in the labor market. Second, household preferences are heterogeneous. This is in contrast to canonical models like Atkinson and Stiglitz (1976), which yield the classic result that commodity price interventions like nonlinear fuel prices are undesirable relative to income taxation. In addition to the practical impossibility of income taxation in our setting, theoretical literature demonstrates how the Atkinson and Stiglitz result can break down when household preferences are heterogeneous (Saez, 2002; Ferey et al., 2024; Doligalski et al., 2025). Our model allows for preference heterogeneity that correlates with both the planner's distributional preferences and the observable characteristics available for targeting.

Our work is closely related to the set of studies making empirical comparisons of cash and in-kind transfer approaches. While we focus on redistributional motives for in-kind mechanisms, other recent empirical work quantifies the case for in-kind transfer policies with other motives in mind – smoothing price risk (Gadenne et al., 2024), curtailing private sector market power (Jiménez-Hernández and Seira, 2022), moderating general equilibrium price effects of cash transfers (Cunha et al., 2019), paternalism (Cunha, 2014; Chorniy et al., 2025), and political economy constraints (Bearse et al., 2000). In the most similar work to ours, Gadenne (2020) uses a Ramsey-style tax reform framework to quantify the welfare effects of a nonlinear commodity price under redistributional preferences for ration shops in India. We focus on the role of the information set in determining the relative redistributional effects of nonlinear subsidies versus cash transfers. We contribute empirically by exploiting variation generated by a large price reform to estimate elasticities, and are the first to document the role of limited information in optimal design of fuel subsidy policies.

A large related literature documents the distributional effects of either in-kind or cash approaches. The targeting effects of in-kind screening mechanisms are established for a wide range of settings and mechanisms. Nonlinear pricing (Borenstein, 2012; Szabo, 2015; Abubakari et al., 2024, e.g.) can achieve desirable targeting in electricity, water, and fuel markets. Other in-kind screening mechanisms shown to achieve desirable distributional outcomes include conditional cash transfers[5], rationing, and program enrollment design (Rafkin et al., 2023; Bergstrom and Dodds, 2021; Gadenne, 2020; Russo, 2024; Finkelstein and Notowidigdo, 2019; Dupas et al., 2016, e.g.). Screening mechanisms can achieve other targets besides progressive redistribution. In environmental markets, for example, mechanisms encourage take-up by "additional" rather than inframarginal agents for conservation or emission reduction (Jack and Jayachandran, 2019; Aspelund and Russo, 2024). Another literature documents the effectiveness and limitations of targeting cash transfers using observables (such as via proxy means testing), community targeting, and hassles (Hanna and Olken, 2018; Banerjee et al., 2020; Brown et al., 2018; Alatas et al., 2012, 2016, e.g.). We directly compare and combine in-kind and cash redistributional approaches and characterize the features of household characteristics which determine optimal policies.

Finally, a large policy literature on fuel subsidies in developing economies provides essential context and qualitative, descriptive, and simulation analysis of these policies (e.g. Rentschler, 2016; Yusuf and Resosudarmo, 2008, 2012; Yusuf et al., 2017 for Indonesia). We build on this foundational evidence by exploiting quasi-experimental variation to estimate household preferences and developing a model of subsidy reform in the presence of limited information to take to the data.

We proceed by introducing the theoretical model in Section 2. Section 3 provides context on fuel subsidies and the BLT cash transfer program in Indonesia, and describes our data. In Section 4 we discuss identification of our empirical models of demand and supply, and describe our approach to welfare measurement and our optimization algorithm for determining counterfactual nonlinear fuel pricing. We discuss results in Section 5 and conclude in Section 6.

2 Theoretical Model

We model the problem of a planner with a distributional target (welfare weights) who has access to cash and in-kind transfer mechanisms. She compares aggregate weighted welfare from the cash mechanism with aggregate weighted welfare under the optimal fuel subsidy, that is, the fuel subsidy that optimally trades off the planner's distributional preferences with her preference for efficiency. We outline the model in the following order: household types and preferences (demand), the planner's problem for the optimal fuel subsidy, cash transfer design, and finally the planner's choice between the cash or in-kind approach. Our model is developed from ADK, Kang (2020), and Pai

[5] Here we characterize conditional cash transfers as in-kind (payments associated with consumption of some kind) in the tradition of public finance and microtheory, whereas they are typically characterized as falling under the cash transfer category in development economics.

and Strack (2022).

While we begin by comparing a pure fuel subsidy scheme to a pure cash transfer scheme, it may be the case that an optimal combination of both outperforms a single policy. Intuitively, as long as fuel preferences and household observables contain distinct information that is predictive of household need, an unconstrained optimal mechanism will condition on both types of characteristics. In the theoretical model we discuss the policies separately, as this corresponds to the typical cash vs. in-kind policy choice faced in many settings, as well as illustrates their distinct (dis)advantages. In empirical analysis, we quantify the welfare effects of both the separate and combined interventions.

A continuum of agents have types (λ, θ, i) distributed according to CDF F. θ are parameters governing household preferences, λ are welfare weights which enter the planner's social welfare function, and i are observable characteristics. Observable characteristics are characteristics observed by the planner for all households in the population. We suppose that distributional preferences λ are a function of a welfare-relevant metric like household income or total consumption. Crucially, household consumption and thus λ, are not in the set of observable characteristics.

For the Indonesian setting, we will adopt total per capita household consumption as this welfare-relevant metric for two reasons. First, it matches the government's targeting approach in the BLT cash transfer, and second, household survey reports of consumption are the widely-used metric of poverty in developing countries, over direct records of income (Deaton, 2003).

We consider mechanisms of the form $p_i(q)$, which nests both cash and fuel subsidy policies. Fuel subsidy (FS) mechanisms take the form

$$p_i(q) = p(q) \text{ s.t. } 0 \leq p(q) \leq cq. \tag{FS}$$

The first feature of fuel subsidies is potential nonlinearity. Schedule $p(q)$ need not take the form nq for some constant n. The second feature is that price schedule $p(q)$ does not depend on i. Third, prices may not be negative. In particular, the fuel subsidy cannot feature a lump sum transfer to households by letting $p(0) = -m$ for some constant value m. Finally, we enforce that fuel policies are indeed subsidies by requiring that they charge no more than total cost under full international fuel (linear) price c. In other words, they cannot generate revenue. These last three restrictions represent departures to the mechanisms which are the focus of theory literature, and we discuss these choices in detail in Section 2.4. We later relax several of them in our empirical analysis.

Targeted cash transfer (CT) mechanisms take the form

$$p_i(q) = cq + t_i. \tag{CT}$$

Under a cash transfer mechanism, fuel is sold at constant marginal cost c and cash transfers are assigned based on observables i.

Facing mechanism $p_i(q)$, an agent of type θ has indirect utility

$$v(p_i(q);\theta). \tag{V}$$

The planner decides how to allocate a budget of B dollars between the two policy alternatives. We model each of these policies in turn, then return to the policy choice. We assume that the planner's distributional preferences are invariant to the mechanisms themselves. That is, we do not allow transfers via fuel or cash to a household to induce a reweighting of distributional preferences.

2.1 Optimal Fuel Subsidy

We first consider the sub-problem of designing the fuel subsidy of total budget B that maximizes the planner's objective, i.e., that optimally trades of equity and efficiency. With slight abuse of notation, we denote marginal distributions of types with subscripts, e.g. $F_{\lambda,\theta}$ as the marginal distribution of (λ, θ) after integrating over i.

The planner chooses a price schedule over fuel, $p(q)$ to maximize a welfare-weighted sum of utilities subject to the budget constraint. She solves

$$\begin{aligned} \max_{p(q)} \quad & \int_\theta \int_\lambda \lambda v(p(q);\theta)\ dF_{\lambda,\theta}(\lambda,\theta) \\ \text{s.t.} \quad & \int_\theta (cq - p(q))\ dF_\theta(\theta) \le B, \\ & 0 \le p(q) \le cq \end{aligned} \tag{1}$$

where B is the total policy budget and c is the constant marginal cost price of fuel in the free market. The planner procures fuel at free market cost c and resells it to the consumer according to the optimal price schedule, $p(q)$. The optimal schedule is, in general, nonlinear. In particular, it can be shown under specific forms of utility that the optimal price schedule is only linear when household Myersonian "virtual values" are linear in household consumption types (Pai and Strack, 2022).[6] In Section 2.4 we discuss several departures from and restrictions on the nonlinear solutions offered in the mechanism design literature that we explore in our empirical exercises.

2.2 Targeted Cash Transfer

Cash transfer program t_i follows the style of the 2005 BLT program: it aims to divide the program budget of B dollars equally among the lowest X% of households by total consumption. Consumption is unobservable, so cash is assigned based on a prediction of consumption $\hat{\lambda}(i) = \mathbb{E}[\lambda|i]$ using observables i.

How does the planner predict consumption if consumption is unobserved? While the planner does not observe individual realizations of consumption for every household in the population, recall

[6]This is true in our model if we suppose that $u(q,\theta) = \theta r(q)$ for some increasing, concave q.

that the planner observes the distribution of household types, and thus the population distribution of household consumption. This allows her to form the expectation function $\mathbb{E}[\lambda|i]$. In practice, this corresponds to observing consumption in a nationally-representative subsample survey that can be used to form a prediction of consumption using observable characteristics, described in detail for our Indonesian setting in Section 3.2, of often referred to as "proxy means testing".

Using prediction $\hat{\lambda}(i)$, cash assignment then follows the rule:

$$t_i = \begin{cases} \frac{B}{0.X} & \text{if } \hat{\lambda}(i) \geq \hat{\lambda}_{1-0.X} \\ 0 & \text{else.} \end{cases}$$

All households below the X^{th} percentile of the distribution of $\hat{\lambda}$ receive an equal portion of the policy budget, and other households receive 0.

2.3 Optimal Policy

The planner compares welfare under the optimal fuel subsidy mechanism with welfare under a targeted cash transfer, evaluating the following expression:

$$\underbrace{\int_\theta \int_\lambda \Big(\lambda v(p^*(q);\theta)\Big) dF_{\lambda,\theta}(\lambda,\theta)}_{\text{fuel subsidy}} \lesseqgtr \underbrace{\int_i \int_\lambda \int_\theta \Big(\lambda\theta v(cq + t_i^*;\theta)\Big)\ dF(\lambda,\theta,i)}_{\text{cash transfer}}. \tag{OBJ}$$

The left hand side quantifies welfare under the optimal fuel subsidy $p^*(q)$. The right hand side captures welfare under cash transfer program t_i^*, where fuel is sold at a (linear) marginal price equal to the constant marginal cost of supply c.

The relative covariance of welfare weights λ and consumption types θ, versus λ and observables i, will pin down the preferred policy. When consumption types are highly informative of income, the planner can offer initial units of fuel at a heavily-subsidized price to increase the consumption of low-income types. Keeping subsequent units of consumption at a higher price, she limits transfers towards high-income types. In the cash transfer alternative, she loses the opportunity to progressively-target fuel allocations, resulting in the most efficient fuel allocation at the expense of equity. Instead, she generates welfare gains from equity to the extent that i, and thus t_i, correlates with distributional preferences λ.

A key comparative static we explore in counterfactuals are changes in the observable set i. As the observable set becomes more (less) informative of household income, total welfare under the cash transfer approach (the right hand side of OBJ) increases (decreases) and cash transfer becomes more (less) appealing. Whether or not additional information makes the cash approach relatively more favorable than in-kind transfers depends on the *joint distribution* of preferences θ and the new information in i. Changes in the information structure alter the policy tradeoff when they provide new information, *conditional* on the targeting capacity already generated by preferences (ADK).

To make this point more formally, suppose the following indirect utility function:

$$v(p_i(q); \theta) = \theta\nu(q) - p_i(q).$$

Under these preferences, households' choices of q fully reveal their consumption types θ. We assume this structure for exposition, only in this section, since under the more general preferences given in (V), choices q reveal *information about* type θ but need not fully identify θ. Let

$$\lambda(\theta, i) = \mathbb{E}[\lambda|\theta, i],$$

the planner's expectation about household welfare weight given consumption type θ and observable characteristics i. Intuition about when nonlinear fuel pricing offers useful targeting comes from examining the variation in $\lambda(\theta, i)$ conditional on i, that is, the planner's expectations about household welfare weight (consumption) after observing consumption type θ, *conditional* on a given set of observables i. When there is large degree of dispersion in expected weights $\lambda(\theta, i)$ for a *given value* of i, consumption types are informative of welfare weights beyond the targeting information available via i under a cash transfer program (ADK).

While our model generates welfare comparisons across policy alternatives for a given budget, it does *not* provide a framework with which to evaluate the optimal program budget. Welfare under the model is (weakly) increasing with the size of the budget for any policy alternative, as larger transfers make households better off. A measure of the marginal value of the next best use of public funds would be required to comment on the optimal program budget size, which is outside the scope of this analysis.

2.4 Constraints on In-Kind Mechanisms

In-kind mechanisms we explore depart from those guided by the theory in two ways. First, the very best in-kind mechanisms will make use of the full information set and feature a menu of fuel price schedules indexed to household observable characteristics i (policies $p_i(q)$). In practice, this could involve offering heterogeneous prices throughout the country on the basis of location, or even conditioning price on other observable household-level characteristics. We exclude such mechanisms from analysis for real-world implementation considerations and computational limitations. Political economy concerns around the fairness or complexity of such mechanisms may arise in practice.

Our second departure from the theory relates to the treatment of lump-sum payments. We partition cash versus in-kind mechanisms in the style of the applied and policy literatures, delineating cash payments from policies manipulating the prices of goods. Mechanism design literature, including ADK, forms this partition on the basis of the information set. Since lump sum payments to all individuals in a population require no information, they are assumed to be available as part of in-kind mechanisms. We adopt the more applied delineation to begin with, providing results on nonlinear fuel prices that do not involve lump sum payments, but later provide empirical results *with* such payments. We view this ability to explore variations of optimal fuel policies as an advantage of simulating the model. Closed form solutions to similar models in the mechanism design literature don't explore in-kind mechanisms common in the real world such as nonlinear pricing without lump-sum transfers, or piecewise linear pricing.

The focus of this paper is on fuel subsidies as in-kind redistributional policies. As such, our main results focus on nonlinear fuel prices bounded above by international free market prices, and fuel policies that don't generate revenue with which to increase the cash transfer budget. It may be the case, however, that policies involving fuel taxes and revenue generation outperform all other mechanisms. While this is not the primary focus of our work, we explore such policies in counterfactuals and provide empirical results on taxation.

3 Context and Data

3.1 Energy Subsidies and the Indonesian Fuel Subsidy

The government of Indonesia has controlled and subsidized prices of consumer petroleum products since 1967. During the early 2000s, kerosene was used as cooking fuel to power kerosene stoves. It was consumed by 90% of households.[7] Gasoline was the primary transportation fuel for households owning motor vehicles, with 23% of households using it. Indonesia's state owned enterprise, Pertamina, implemented the subsidy, selling fuel throughout the country at fixed national retail prices. Official national subsidized prices were reformed only by government reform. We plot the time series of national prices and Singapore product spot prices for both fuels from 2001-2007 in Figure 1 in IDR per liter. Kerosene was heavily subsidized – the official national price was on average 33% of Singapore kerosene spot prices over the years 2001-2007. National gasoline prices were on average 88% of spot prices.

For both the gasoline and kerosene markets, distribution involves a combination of Pertamina suppliers and informal suppliers. In the gasoline market, Pertamina retail stations sell gasoline at the subsidized price and then claims reimbursement from the government for the deficit it incurs by selling fuel up to demand at prices below production cost.[8] In regions with little access to Pertamina retail, informal intermediary traders buy gasoline from Pertamina retailers at the subsidized price, transport it to local markets, and then resell it at a marked-up price. In the kerosene market, fuel was[9] distributed from Pertamina "agents" at the subsidized price to informal sellers who resold the fuel to households after applying a markup.

We focus on the years 2005-2007, during which the fuel subsidy was at the heart of national fiscal policy reform. Spending on the fuel subsidies, including consumer and commercial fuel,

[7]Average from Susenas household surveys in 2003 and 2004.

[8]The full price benchmark is based on Singapore fuel prices, multiplied by a parameter capturing distribution costs.

[9]The country launched a national campaign in 2007 to phase out kerosene as a primary cook fuel and replace it with LPG.

represented 30% of the government budget in 2005. To mitigate increasing subsidy budget shares, the government enacted a fuel price reform in 2005 which resulted in an 186% increase in the official price of kerosene and a 88% increase in the official price of gasoline.

We plot fuel consumption across the household total per capita consumption distribution in Appendix Figure A1. In the first row, we compute the share of total household expenditure allocated to fuel, including households who consume zero of each fuel type. The second row excludes households with zero fuel consumption. The lowest income households allocate over 3% of their monthly total expenditure to kerosene, and the highest income households allocate under 2% to kerosene. In the gasoline market, low-income households consume very little gasoline in the population average since most do not use the fuel at all, as summarized in Appendix Figure A2. We calculate the implied total transfer across the expenditure distribution in Figure 2. Since higher-income households consume more of both fuel types, more of the subsidy transfer accrues to higher-income households.

3.2 Bantuan Langsun Tunai (BLT): Cash Transfer Program

Alongside the 2005 fuel price reforms, the government of Indonesia created a one-time cash transfer program, named Bantuan Langsun Tunai, or BLT, with the advertised purpose of compensating households for rising fuel costs. The program aimed to make cash payments to the poorest 30% of households. Payment consisted of four quarterly installments of roughly 30 USD, representing 15% of quarterly expenditures for the average household recipient.

Without population-level measures of wealth or income in hand, the government employed a two-step approach for identifying its target households. In the first step, it asked community leaders to provide a list of potentially-eligible households to program administrators. In the second, the government then surveyed all households on these lists to record a set of observable characteristics (i in our theoretical model) that are easy to measure and difficult to manipulate (Coady et al., 2004). Observable characteristics used in the proxy means model include demographic characteristics of household members, dwelling characteristics like roof type and home ownership, and sanitation measures like drinking water source. While the exact model is not public, Bazzi et al. (2015) and Hanna and Olken (2018) produce close replicas of the model.[10] Banerjee et al. (2020) find evidence in Indonesia that households do not manipulate or misreport asset ownership for censes used to target social assistance programs.

Using the collected observable characteristics, the government formed a "proxy means" predictive model of total household consumption as a function of observables. For the left hand side, the government used data on total per capita household consumption from nationally-representative household survey data. We describe this data in Section 3.3 and use it in our own empirical exercise. It estimated model parameters, predicting consumption with observable household characteristics available both in the nationally-representative sample and in the targeting survey administered to

[10] See Table 2 in Bazzi et al. (2015) for estimates from a model attempting to replicate the proxy means test of the BLT program. See Figure 3 in Hanna and Olken (2018) for a plot of model fit.

all households. This prediction of household income was then used for transfer assignment. Hanna and Olken (2018) study the errors of inclusion (non-targeted households receiving the transfer) and exclusion (targeted households omitted from the transfer) generated by the BLT proxy means model.

Why doesn't the government directly observe or collect total per capita household consumption for the population? This is the specific information friction that limits the effectiveness of a targeted cash transfer program. Several factors make direct identification of low-income households costly and challenging. First, surveying the population is difficult and expensive, and population censes in developing settings rarely record income (Tarozzi and Deaton, 2009). Second, survey responses about household income are found to be unreliable, especially when tied to the targeting of public benefits (Banerjee et al., 2020). Finally, income is often highly observable in settings with large formal labor sectors, but the share of workers employed in the formal sector in Indonesia in 2000 was less than one third (International Labour Organization, 2003). In lieu of collecting household income for the population, detailed but costly household consumption surveys characterize household income and wealth more accurately and are often administered to a nationally-representative subsample (Deaton, 2003). Working with subsample data on household consumption necessitates a predictive approach, wherein the government assigns transfers on the basis of a limited set of observable targeting characteristics that it *does* observe for the population. Similar factors constrain government information sets worldwide, and we summarize the types of observable proxies used in transfer programs across a large number of countries in Appendix Table A1.

The 2005 BLT transfer was progressively targeted, but fell short of meeting the targeting goal. We plot BLT receipt across household expenditure quintiles in Figure 3. Just over half of households in the poorest quintile received the transfer, and 45% of the transfers were received by the non-targeted group.[11] These mistakes reflect model fit of the prediction, or the degree to which $\mathbb{E}[\lambda|i]$ fits λ using our model notation. They also reflect implementation challenges arising in the distribution of cash, which we discuss further in Section 4.6.

3.3 Data

To bring our theoretical model to the data, we require measures of government-set fuel prices, local fuel prices, households characteristics including total consumption, fuel quantity, and an instrument for identifying the price elasticity of demand. Data on household characteristics including total consumption, local fuel prices, and fuel quantities come from the National Socioeconomic Survey (Susenas), which is collected by the government of Indonesia. The survey records annual nationally-representative cross-sectional household data for a large sample of around 220,000 households, and

[11] This may understate the error of exclusion among the low-income households, as some especially poor individuals without identification or housing remained outside survey data. Unfortunately our analysis will not reflect outcomes among these households.

a smaller nationally-representative panel dataset of 10,000 households for the years 2005-2006.[12] We merge the panel records with a supplemental Susenas survey on the implementation of the 2005 BLT program for the same set of households. From this survey we observe eligibility and receipt of the cash transfer.

We combine household survey reports of fuel expenditures and fuel quantities to measure fuel prices, which vary across local markets due to the presence of informal sellers. The consumption module of Susenas asks respondents to report total expenditure and total quantity consumed of fuel over the last month. From these we observe a household-level estimate of fuel "unit price". In accordance with our model of fuel supply, we assume that fuel prices are constant within local markets, and that variation in household-level unit prices within local markets result from measurement error. We take the median fuel price within subdistrict as the local market level measure of fuel price, drawing from pre-reform 2003 and 2004 data. Median subdistrict prices from these years are displayed in Appendix Figure B1. We combine these measures of subdistrict fuel price with our model of intranational fuel trade to estimate local markups. For the 2006 wave Susenas, fuel quantity records are missing. To infer household fuel quantities, we combine household fuel expenditures with our estimates of local markups, described in detail in Section 4.1.

Indonesian national fuel subsidy prices are available in many public sources, and we take them from Beaton and Lontoh (2010). Reforms to this price offer the instrument we use to identify the price elasticity of demand. We draw international fuel prices from the International Energy Agency's archived Oil Market Reports, which record average monthly spot prices for gasoline and kerosene in multiple global markets. We use Singapore spot prices to represent the local import market.

4 Model Identification and Estimation

The empirical primitives of our theoretical model are an estimate of the joint distribution $F(\lambda, \theta, i)$, an estimate of utility function $u(\cdot)$, and estimates of intranational supply parameters. We discuss first the supply model and estimation, and second the approach to the household type distribution and preferences.

4.1 Supply

Spatial price variation arises in Indonesia due to heterogeneity in the distribution locations of Pertamina fuel and the presence of informal sellers. In the kerosene market, and in locations where Pertamina retail of gasoline is distant, the government sets official prices $p_o(q)$, intermediaries buy at $p_o(q)$, and finally resell at $p_d(q)$ in their local destination d. Our model of intranational supply by local intermediaries serves two purposes: it rationalizes observed spatial price dispersion, and allows us to form a measure of fuel prices for the Susenas waves where unit prices are missing.

[12] The panel data include a 2007, which we omit for data quality concerns in the household consumption and expenditure section. See further discussion in Appendix Section B.

We assume that a large number of identical, perfectly competitive intermediaries operate in local market d. They transport q_d liters of fuel from their nearest source o_d to market at total cost

$$C(q_d) = (p_o + x_d)q_d,$$

where x_d are trade costs associated with transporting fuel to market d. We assume these trade costs are fixed over time. This assumption is discussed further in Appendix Section B.2, where we report subdistrict prices from years in which p_o doesn't vary. Under our model, local market prices are then given by the first order condition of the supplier cost-minimization problem:

$$p_d = (p_o + x_d).$$

The empirical task is to estimate local market-specific trade costs x_d. We identify these trade costs with spatial variation in the fuel prices reported in the household survey data. After computing median price within each subdistrict, we use these prices from multiple time periods t (2003 and 2004[13]) to estimate locality-specific trade costs x_d with fixed effects:

$$p_{dt} = p_{ot} + x_d + \varepsilon_{dt}.$$

We thus assume that variation in subdistrict prices leftover after accounting for official subsidy prices and spatial (subdistrict) fixed effects is attributable to idiosyncratic errors ε_{dt}, coming from measurement error in household-level unit prices. This is similar to Deaton (1988) and Deaton (1990), who assumes that prices are common within village or locality, and all remaining dispersion in unit prices is the result of measurement error. To lend empirical evidence to this assumption, we explore the dispersion in household unit prices for kerosene and gasoline compared with rice, which featured national intervention to ensure price stability and a large number of independent and competitive retailers. The average coefficient of variation of rice unit prices within subdistrict is larger (0.08) than it is for kerosene (0.06) and gasoline (0.05) across 2005 and 2006.

We report the distribution of estimated intranational trade costs for subdistricts in Appendix Figure A3. With supply estimates in hand, we can recover local fuel prices p_{dt} for any year t using the supply model and the official government price p_{ot}. Since household fuel quantities are missing in some years of our household panel, we form an estimate of quantities using household monthly fuel expenditures and these estimated local prices. For consistency across years, we use fuel quantities estimated using this method for all of the remaining analysis.

We visually inspect the accuracy of this quantity estimation using the 2005 panel data, which contains direct household reports of fuel quantity. Appendix Figure A4 plots estimated quantities against reported quantities. 2005 is omitted from the supply estimation, offering us an out-of-sample test of fit.

[13] We exclude 2008 data since a large national price reform occurred during the surveying period, making p_{ot} unobservable.

4.2 Household Type Distribution and Preferences

We seek empirical estimates of the joint distribution of household types $F(\lambda, \theta, i)$, and household preference function $v(p;\theta)$. Recall that i are observable characteristics and come directly from the data. We assume welfare weights λ are a function of household consumption, and show results under multiple functional form assumptions. We discuss our choice of welfare weight functions in Section 4.4. It remains, then, to specify preferences $v(p;\theta)$ and identify the distribution of preference parameters θ.

We begin by relaxing the quasilinearity implicit in our theoretical model, allowing for an income effect in household demand for fuel, generalizing household preferences to $v(p, y; \theta)$ for household income y. We specify a Marshallian demand function and recover the corresponding expenditure and indirect utility functions using Roy's identity. We assume a household's status as consumer or non-consumer of each fuel is static and fixed based on 2005 fuel usage.[14] Let $\theta = (\alpha, \gamma, \beta)$ and Marshallian demand be given by

$$\log q = \alpha + \beta \log p + \gamma \log y \tag{2}$$

for a household facing price p and income y. Price elasticity β will be allowed to vary across income groups, and income elasticity γ captures the direct income effect.

The corresponding indirect utility function for evaluating welfare is given by

$$v(p, y; \theta) = \frac{1}{1-\gamma} y^{1-\gamma} - e^{\alpha} \frac{p^{1+\beta}}{1+\beta}, \tag{3}$$

and since $y = e(p, u)$ and $v(p, y; \theta) = u$ in equilibrium, the corresponding expenditure function is

$$e(p, u) = \left[(1-\gamma) \left(u + e^{\alpha} \frac{p^{1+\beta}}{1+\beta} \right) \right]^{\frac{1}{1-\gamma}}. \tag{4}$$

To complete the model we must identify $\theta = (\alpha, \beta, \gamma)$. We identify β using the price reform of 2005. Two leading sources of endogeneity threaten the identification of the price elasticity of demand via a simple regression of quantities on local prices. Likely the most important source of endogeneity in this setting could arise from spatial correlation between intranational trade costs and household characteristics. In particular, remote places with high prices due to high intranational trade costs are home to households with different characteristics. Some correlation may remain after controlling for income. We address this by using within-subdistrict variation in prices over time generated by the 2005 reforms. After isolating subdistricts, all remaining variation in price is due to the price shock in 2005. Another potential source of spatial endogeneity is heterogeneous conduct among local intermediaries. Suppliers with market power set prices according to the shape

[14] 6% of households in the kerosene market and 15% of households in the gasoline market moved consumption status between 2005 and 2006. This movement on the extensive margin is uncorrelated with movement in price in the kerosene market. For gasoline, an additional 3% of households consume gasoline in 2006 than in 2005.

of demand. We assume away this type of endoegenity in modeling intermediaries as perfectly competitive.

Identification using within-subdistrict temporal price variation is threatened by the second main source of potential endogeneity: contemporaneous trends affecting household demand for fuel. The identification assumption is that the change in prices from pre-reform to post-reform for a given subdistrict is orthogonal to unobserved changes in demand for fuel. If the government reformed prices in anticipation of an unobserved fuel demand shock, estimates would suffer omitted variable bias. We provide suggestive evidence against such trends using fuel consumption data from several periods pre- and post- price reform in Figure 4. Demand for fuels appears not to be trending in the years leading up to the shock (highlighted in dark red). The timing of other price reforms is marked in light red. Our approach assumes that no contemporaneous demand shock affect household fuel consumption between 2005 and 2006.

If our supply model is misspecified, we will suffer bias in our estimated price elasticities. We assume informal intermediaries are perfectly competitive and apply a fixed location-specific markup over the official price of fuel, described in Section 4.1. We impose this model of supply in estimating demand parameters using model-generated prices, so that all variation in prices within subdistrict comes from the reform. If intermediaries in fact have some amount of market power, or if trade costs vary over time, we may under or over-estimate subdistrict prices post-2005 and therefore under or over-estimate consumer price elasticities. If, for example, trade costs rose between 2005 and 2006, we would under-estimate the size of the price reform within subdistricts and over-estimate price sensitivity.

The income effect γ is identified from cross-sectional variation in household income within subdistrict. We estimate household values of $\theta_g = (\alpha, \beta_g, \gamma)$ for each income tercile $g \in \{1, 2, 3\}$ with the following:

$$\log q_{ht} = \alpha + \sum_g \beta_g \log p_{dt} D_g + \gamma \log y_h + \sigma_d + BLT_{ht} + \varepsilon_{ht} \tag{5}$$

using household-time fuel quantities q_{ht}, subdistrict-time fuel prices p_{dt}, and subdistrict fixed effects σ_d. Since the price reform coincided with the introduction of the cash transfer program, we control for household receipt of the cash transfer in period t, BLT_{ht}. With $\hat{\theta} = (\hat{\alpha}, \hat{\gamma}, \hat{\beta})$ in hand, estimated as a function of household income as in Equation 5, we have formed the empirical counterpart to $F(\lambda, \theta, i)$.

4.3 Computation of Optimal Nonlinear Prices

Given preferences and supply, we search for nonlinear, two-part, fuel price tariffs. The mechanism design literature offers closed-form solutions to models like the one we present in Section 2. As discussed in that section, optimal nonlinear prices are, in general, increasing functions $p(q)$. Since we generalize the preferences, relaxing the quasilinearity of household preferences as presented in

Section 4.2, we forgo closed-form solutions. Instead we use numerical optimization to solve for optimal nonlinear fuel policies. To make the problem computationally tractable, we restrict fuel policies to the class of two-part increasing tariffs, described in detail below.

Let p^0 denote prices under the status quo, and $p^1(q)$ denote the counterfactual nonlinear price schedule. We seek the policy $p^1(q) = (p_1, p_2, k)$ that maximizes weighted welfare subject to a budget constraint, solving Equation 1. Price schedule $p^1(q)$ takes the following form:

$$p^1(q) = \begin{cases} p_1 q & \text{if } q \leq k \\ p_1 k + p_2(q-k) & \text{if } q > k \end{cases}. \tag{6}$$

Consumers can buy up to k liters of fuel at price p_1, after which they are charged p_2 for subsequent liters.

Evaluating welfare at nonlinear prices requires additional care given that the demand, indirect utility, and expenditure functions (Equations 2-4) we specified are specific to linear pricing environments with constant marginal price p. We follow Reiss and White (2006) and You and Lim (2017) in employing a Hicksian approach to evaluate exact welfare under nonlinear pricing. We measure welfare using equivalent variation, quantifying the amount of cash that would make a household indifferent between a new pricing policy and the status quo. We form equivalent variation (EV) as

$$EV(p^0, p^1(q), y; \theta) = y^e - y = e(p^0, u^1; \theta) - y, \tag{7}$$

where y^e is the amount of income that would make the household as well off pre-reform as they would be post reform. This value is equivalent to the amount of expenditure required at pre-reform (linear) prices to achieve post-reform utility level u^1, less pre-reform expenditure. Replacing utility with equivalent variation, the objective (OBJ) can then be reformulated as

$$\underbrace{\int_\theta \int_\lambda \Big(\lambda EV(p^0, p^1(q), y; \theta)\Big) dG(\lambda, \theta)}_{\text{fuel subsidy}} \lesseqgtr \underbrace{\int_i \int_\lambda \int_\theta \Big(\lambda t_i\Big)\; dF(\lambda, \theta, i)}_{\text{cash transfer}}. \tag{8}$$

If post reform prices $p^1(q)$ were simply another linear price, then u^1 could directly be recovered from the indirect utility function in Equation 3. Under nonlinear price schedule $p^1(q)$, indirect utility is given by

$$u^1 = \begin{cases} V(p_1^1, y) & \text{if } q^1 \leq k \\ V(p_2^1, y + (p_2^1 - p_1^1)k) & \text{if } q^1 > k \end{cases}$$

where q^1 denotes demand under schedule $p^1(q)$ (You and Lim, 2017).

How do we determine demand q^1 under nonlinear pricing? Let $d(p, y)$ be the Marshallian demand function implied by Equation 2. Then we can assess demand under block pricing using "virtual income"

$$\log q^1 = \begin{cases} d(p_1^1, y) & \text{if } d(p_1^1, y) \leq k \\ d(p_2^1, \tilde{y}) & \text{if } d(p_2^1, \tilde{y}) > k \\ k & \text{else} \end{cases}$$

with virtual income $\tilde{y} = y - (p_2^1 - p_1^1)k$.

To estimate (p_1, p_2, k) we solve the following constrained optimization problem:

$$\max_{p_1, p_2, k} \sum_h \lambda_h EV(p^0, p^1(q_h), y_h; \hat{\theta}_h) \tag{9}$$

$$\text{s.t. } \sum_h (c\hat{q}_h - p^1(\hat{q}_h)) \leq B. \tag{10}$$

Additional details on the approach to numerical optimization are provided in the Estimation Appendix C. We constrain p_1 above 200 IDR/liter for kerosene and 300 IDR/liter for gasoline to avoid moving far outside the support of our price data, and to avoid modeling demand at 0 prices.

4.4 Welfare Weight Functions

For our main results we assume welfare weights are defined according to the step function displayed in Appendix Figure A5. We select a weight function that place a high, uniform weight on the poorest third of the distribution because this is a class of functions that rationalizes a uniform targeted cash transfer towards this group. As such, the design of the BLT program lends evidence towards distributional preferences of this form. We examine the robustness of welfare gain estimates under counterfactual policies to an alternative specification of welfare weights based on marginal utility of income in our results section.

We note several limitations with this approach to welfare weights. First, while the design of the 2005 cash transfer lends evidence to a welfare weight function that places uniform high value on the poorest 30% of households, it does not offer guidance on other features of this function, such as the dispersion of weights across groups or the shape of the function for higher income households. We also acknowledge that making weights a function of income or consumption alone is itself a large restriction. Empirical research aiming to quantify redistributional preferences as a function of stated values and observed choices or policies documents a large range of preferences. Notably, in Indonesia, Alatas et al. (2012) find evidence that local leaders and community members exhibit a notion of poverty that includes more factors than just per capita consumption, such as recent illness or a widowed household head.

4.5 Externalities

Consumption of kerosene and gasoline generate several categories of external costs. Both fuels generate global costs via the production of carbon dioxide, as well as unique forms of local pollution. We focus on climate damages when computing the externality costs of each policy counterfactual relative to baseline emissions and add these costs to the estimated equivalent variation. We assume the government designs policies to maximize welfare-weighted utility, and does not internalize these external costs when designing policy. We value the global social costs of climate change generated by carbon dioxide emissions according to the US EPA's 2020 central estimate for the Social Cost of Carbon, at $190 per metric ton, which translates to 3,430 IDR/liter for kerosene and 3,156 IDR/liter for gasoline (2006 IDR).[15]

This exercise excludes important categories of local externalities. For kerosene, we exclude the health and mortality costs of indoor air pollution generated by using kerosene cookstoves, as well as any contribution to ambient outdoor local air pollution. In the gasoline market, we exclude local externalities in the forms of local pollution and road congestion.

4.6 Implementation and Leakage

For simplicity we abstract from targeting frictions that may arise in the implementation of nonlinear pricing, and similarly assume away cash transfer implementation frictions. The costs of frictions in implementing nonlinear pricing are uncertain, but likely non-zero. Nonlinear pricing for consumption goods like food and fuel is implemented in ration systems in many countries (Gadenne, 2020). They require a form of identification so that households consumption can be recorded over a time period. Indonesia has recently piloted a similar system for gasoline pricing in Jakarta, tracking identity and consumption via a mobile app.

Consumers and informal traders could find profitable opportunities for resale of subsidized fuel under nonlinear pricing. We do not attempt to quantify the extent to which this form of leakage would erode the targeting effects of nonlinear subsidies. We note that smaller-budget subsidy programs which offer few units of fuel at the subsidized price are less likely to result in such leakage, when household quantity demanded exceeds the quantity available at a subsidized price.

We assume in counterfactuals that households face the nonlinear price schedules, marked up by estimated subdistrict trade costs. Implicitly this assumes the government operates intranational trade. We make this simplifying assumption to avoid modeling how informal traders would best respond to a nonlinear price scheme at official Pertamina retailers.

Implementation challenges in the cash transfer program are easier to observe based on evidence from the 2005 program. Notably, around 2000 local village leaders opted out of the program entirely, citing perceived unfairness associated with the targeting approach (Alatas et al., 2012). Additionally, the implementation survey records household receipt of the first two waves of transfers,

[15] These per liter damage values reflect the assumptions over welfare functions and weights implicit in EPA models, rather than those assumed in our analysis.

which falls short of transfer assignment for reasons related to implementation. These include documented challenges with payment distribution at post offices (World Bank, 2006).

5 Results

5.1 Household Type and Preference Estimates

Table 1 displays estimates of demand elasticities by income tercile, β_g, and estimates of income effect γ from Equation 5. High income households are less price sensitive in the kerosene market, with (absolute value of) elasticity estimates decreasing from 0.35 to 0.31 from the lowest tercile to the highest. High income households are more price sensitive in the gasoline market than their low income counterparts, at 0.14 relative to 0.11. A Wald test rejects that the elasticities are equivalent across income groups at a 1% significance level for both fuels. Higher income households have higher willingness to pay for fuel at all prices.

Our price elasticity estimates are smaller in absolute value than existing fuel price elasticity estimates from Indonesia, which use cross-sectional rather than policy variation for identification (Renner et al., 2019). The smaller estimates are unsurprising given that our approach attempts to eliminate spatial correlation between prices and household characteristics. To the extent that more remote locations feature both high fuel trade costs and lower-income households, coefficients from regressions of quantities on prices would be biased upwards in absolute value.

5.2 Targeted Cash Transfers vs. Nonlinear Fuel Subsidies

We begin by evaluating policies relative to a baseline of 2006 (post-reform) linear fuel prices – national prices of 2,000 IDR/liter for kerosene and 4,500 IDR/liter for gasoline – and no cash transfer program. This 2006 baseline operates in two ways. First, we quantify the welfare gains associated with each policy relative to welfare under 2006 prices. Second, each policy counterfactual costs an additional B IDR relative to spending under 2006 prices. In other words, we take the spending needed to offer fuel at 2006 prices as given, and consider interventions that increase the budget beyond this level. We start by examining individual policies: either cash transfer programs or fuel subsidy policies, each of which costs a fixed budget of B IDR.

Figure 5 plots the welfare gains associated with each policy intervention for a budget of 200 billion IDR. This is a modest sized intervention, representing roughly one sixth of the budget of the BLT cash transfer program. In the first set of bars, unsurprisingly, flat subsidies (linear price discounts) applied to kerosene or gasoline generate the smallest welfare gains. The distributional effects of these flat subsidies, graphed in Figure 6 illustrate why this is the case. The left panels plot the average household transfer (in IDR) implied by the flat subsidies across quintiles of household per capita consumption. The transfer is increasing in household per capita total consumption for both fuels, showing that wealthier households accrue more of this transfer. The right panels display the mean welfare gain, or equivalent variation, associated with each policy, across per capita consumption quintiles. Similarly, higher income households value the flat subsidy policy the most. After accounting for the cost of carbon emissions generated by these subsidies, the welfare gains generated by the flat subsidies are reduced modestly, as plotted in gray in Figure 5.

In the second and third set of bars in Figure 5, we plot the welfare gain associated with two cash transfer programs – first, a transfer of total budget 200 billion IDR assigned to the recipients of the BLT cash transfer, and second, a transfer of the same total budget assigned to all Indonesian households, titled "Lump Sum". The lump sum transfer, by design, generates a distribution-neutral transfer to households. It yields an aggregate welfare gain that is 68-147% greater than that of the flat subsidy approach. Since the flat subsidy approach generates a regressive intervention, a distribution-neutral transfer to all households generates a higher welfare gain. The BLT assignment, thanks to the government's targeting information strategy, is much more progressive and generates 142-258% of the welfare gain of the flat subsidy. Figure 6 shows why this is the case – the BLT program much more effectively targets the transfer to the low-income households that are heavily valued under the government's distributional preferences.

In the final two sets of bars we explore nonlinear pricing of fuel. Nonlinear price policies for kerosene and gasoline are estimated using the strategy described in Section 4.3. We begin by discussing nonlinear kerosene policies. The fourth bars display the optimal nonlinear fuel policies of budget 200 billion IDR. Under the optimal kerosene policy, 6 units are sold at 201 IDR/liter, and subsequent units are sold at 3,109 IDR/liter, as plotted in blue in Figure 7.[16] This policy generates 1.2 times the welfare gain of the targeted cash transfer program. Under our baseline of 2006 fuel prices, kerosene is heavily subsidized at a price of 2,000 IDR/liter below the international price of 4,600 IRD/liter. Since we take 2006 fuel subsidy spending as given and introduce policies of an *additional* 200 billion IDR, the kerosene market offers an opportunity for cross-subsidization, where 6 units of fuel are sold below 2006 prices and subsequent units are marked up relative to this benchmark. We find that this cross-subsidy is what allows nonlinear kerosene to generate large welfare gains.

To understand the large welfare gains generated by nonlinear kerosene pricing further, we explore a final counterfactual scenario in the fifth set of bars. We implement the optimal *budget-neutral* nonlinear kerosene price, under which 6 units of kerosene are sold at 285 IDR/liter, and subsequent units are sold at 4595 IDR/liter, as plotted in green on the left panel of Figure 7. The high price of 4595 falls above the 2006 benchmark of 2,000 IDR/liter, and just below the international benchmark price of 4,600 IDR/liter. This policy generates no additional spending relative to the 2006 benchmark. In this way, the government can make a budget-neutral fuel price reform that improves welfare by increasing the transfer to low income households and reducing the transfer to high income households. For kerosene, this policy generates nearly as large (96%) a welfare gain as the BLT targeted cash transfer. Aggregate consumption of kerosene falls under this policy relative

[16] Recall that nonlinear fuel policies also cost a budget of B IDR relative to 2006 baseline spending and cannot be used to generate revenue in this exercise. We examine policies involving fuel taxation and generation of revenue for larger cash transfer programs in Section 5.3.1.

to the baseline, so the welfare gain surpasses that of the cash transfer after accounting for the cost of carbon emissions. Furthermore, most of the welfare gains of the 200 billion IDR nonlinear policy can be generated with this budget-neutral policy – the welfare gain is 80% as large. The large welfare gains generated by both nonlinear kerosene pricing and targeted cash suggests that a combined intervention of both policies may outperform any individual policy.

Nonlinear kerosene pricing offers a promising redistributional opportunity, while gasoline pricing does not. The welfare gain generated by nonlinear gasoline pricing is less than a third as large as the nonlinear kerosene price. It is outperformed by both the targeted and non-targeted (lump sum) transfer, and generates a small improvement over a flat gasoline subsidy. This is driven two factors. The first lies in household preferences for gasoline across the income distribution. Only 23% of households consume gasoline, and gas-consuming households are heavily skewed towards having high incomes, as displayed in Appendix Figure A2. The transfer distribution in Figure 6 illustrates the government's limited ability to design a progressive gasoline subsidy. The second factor limiting the effectiveness of nonlinear gasoline pricing are the high baseline gasoline prices in Indonesia relative to the global market. Under the 2006 benchmark, Indonesian consumers faced full international prices, eliminating the opportunity to introduce a budget-neutral cross-subsidy (without taxation).

To explore the sensitivity of results to the specific welfare weight function chosen (as plotted in Appendix Figure A5), we compute counterfactuals under an alternative function and find qualitatively similar results. We specify alternative welfare weights as the marginal utility of income under our assumed household preferences and pre-policy household consumption levels, discussed further in Appendix Section D. After computing optimal nonlinear fuel pricing using these alternative weights, we report welfare gains associated with each policy in Appendix Figure A6. Results are qualitatively similar, with a nonlinear kerosene subsidy marginally outperforming targeted cash.

5.3 Combined Interventions

A combined policy of cash transfers and nonlinear fuel pricing may outperform a single policy of the same budget for two reasons. First, each transfer approach may provide distinct targeting advantages based on differences between the information contained in the government's targeting observables and households' preferences over fuel. Second, as we discussed in the previous subsection, the government can add a budget-neutral nonlinear kerosene pricing (relative to the 2006 benchmark) while allocating the full budget to cash transfers. We explore distributional outcomes and welfare under two types of combined interventions. The first involves no additional information requirement beyond the nonlinear subsidy, combining a nonlinear fuel price and a *non* targeted lump sum cash transfer to all households in the population. The second makes use of the targeting observables, involving a nonlinear fuel price and a targeted cash transfer.

To compute the optimal combined cash and in-kind interventions given a total policy budget, we solve for the optimal budget share allocated to each of the two policies, cash and fuel subsidy.

In terms of the model, we compute $\alpha^* \in [0,1]$, the share of the total budget assigned to the cash transfer, and nonlinear policy $p^1(q)$, to solve

$$\max_{\alpha, p^1(\cdot)} \int_i \int_\lambda \int_\theta \left(\lambda \left(EV(p^0, p^1(q), y; \theta) + t_i\right)\right) dF(\lambda, \theta, i)$$
$$\text{s.t.} \int_\theta (cq - p^1(q)) dF_\theta(\theta) \leq (1-\alpha)B \quad \text{and} \quad \int_i t_i dF_i(i) \leq \alpha B,$$

where q is the optimal quantity chosen by households given preferences and prices. In the case of the non targeted lump sum transfer, transfers are a fixed value t rather than a function of observables t_i. All households in the population receive transfer t.

Table 2 displays the resulting welfare estimates and nonlinear fuel policies across values of α for a total policy budget of 200 billion IDR. Welfare increases monotonically in the share of the budget allocated to the cash transfer, for both types of cash transfers, and is maximized at $\alpha = 1$ when the entire budget is assigned to the cash transfer. Crucially, however, the full cash allocation *also* features a nonlinear price for the kerosene market. This lump sum combined intervention features a welfare gain that is 164% of that of the targeted cash transfer counterfactual we presented in Figure 5 where fuel remained linearly priced at 2006 prices, and 137% of the pure nonlinear fuel subsidy. This intervention combines the welfare gains of the free nonlinear subsidy (fourth bars in Figure 5) with the gains of the lump sum transfer (third bars). As discussed in Section 2.4, this counterfactual is an empirical counterpart to in-kind solutions in mechanism design models, such as in ADK. Since a lump-sum transfer requires no household observable characteristics it can be a component of an in-kind mechanism. Indeed, in the optimum these transfers are a large component of such mechanisms in our setting. Lump-sum payments help overcome the challenge with pure nonlinear fuel prices we encountered in our first set of results – namely that as the program budget grows, fuel becomes heavily subsidized for all consumers and cannot be well-targeted.

The combined intervention with a targeted cash transfer improves welfare further, pushing welfare up an additional 31 percentage points over the pure targeted cash intervention and an additional 26 percentage points over the pure nonlinear subsidy. Intuitively, this policy adds the targeting advantages of the BLT cash transfer relative to the lump sum transfer. In the case of both combined interventions, once the free nonlinear subsidy is in place, additional dollars shifted away from the cash transfer and into the fuel subsidy do not increase welfare. We display total welfare under both combined interventions, nonlinear fuel pricing with lump sum and targeted cash transfers, in Figure 8 next to the individual policy estimates from the prior subsection.

A combined intervention with gasoline subsidies, in turn, does not improve welfare over a pure targeted cash transfer approach. Even in the highest-information setting, combining the targeted cash transfer with nonlinear gasoline pricing generates no additional welfare beyond the cash transfer alone, as displayed in Figure 8 (third and fourth sets of bars). This occurs because diverting any budget away from the cash transfer into the nonlinear subsidy reduces welfare, shown in Table 2, and there is no opportunity for a free cross-subsidy in the gasoline market. The accompanying "nonlinear" fuel policy is simply the existing flat subsidy.

5.3.1 Taxation

The final combined intervention we explore allows for taxation. Since combined fuel subsidy and transfer policies involve allocating the full budget towards cash, our results suggest that welfare could be improved further by using fuel policy to raise additional revenue for cash transfers. To explore this, we allow p_2 to rise above the international price of fuel and let the fuel policy intervention generate revenue. We consider values of p_2 that represent between a 0-50% tax rate over international prices. Any revenue generated by the fuel market (over the 2006 benchmark level) added on top of the 200 billion IDR cash transfer budget. We describe our approach to estimation for these counterfactuals further in the Estimation Appendix.

The welfare gains generated by the optimal nonlinear fuel price with taxation and cash transfer program are plotted in the last set of bars in Figure 8. For both kerosene and gasoline, this combined intervention outperforms all other policies. We report the details of these polices in Appendix Table A3. Under the optimal kerosene tax and cash transfer program, p_2 features a 50% tax rate, while p_1 also falls above the 2006 benchmark price. This generates a revenue that increases the size of the cash transfer program by 6.6 times over the 200 billion IDR budget. Under the optimal gasoline policy, gasoline is also taxed at a 50% rate after 3 units of consumption, which doubles the cash transfer budget. These policies substantially outperform a pure targeted cash transfer, generating over 3 times (kerosene) and 2 times (gasoline) the welfare gain.

Our findings suggest that policies involving fuel taxation are the most preferred interventions. This finding appears robust given the consistent result that combined interventions should minimize spending allocated towards fuel subsidization and maximize spending allocated towards cash transfers. However, we caution against using our model to explore the optimal tax and transfer policy for three reasons. First and foremost, measuring welfare using equivalent variation is well-suited to comparing multiple interventions but poorly suited to finding the optimal size of a single intervention. As increasingly large taxes fund increasingly large cash transfer programs, the model doesn't capture diminishing returns to these transfers. Second, and relatedly, we do not update welfare weights under our model in response to the interventions themselves. Large targeted cash transfers alter households' position in the income distribution, which is not modeled. Finally, large taxes move prices further outside the support of the distribution used to estimate price elasticities.

5.4 Policy Budget

So far we have considered modestly-sized policy interventions. Now we consider how the optimal policy is affected by the budget size. To explore the relationship between policy budget and the optimal intervention, we plot the welfare gain of each policy against the total policy budget in Figure 9. We report optimal fuel policies and final welfare values for each budget in Table 3. As the total policy budget increases, all policies generate higher welfare gains since the size of the transfer grows. As discussed in Section 2.3, the largest-budget policies generate the highest welfare gains by construction, as there is no notion of a cost of funds within the model. The goal of the exercise is to illustrate relative welfare across policies at any given budget point.

The highest budget under which we compute results, 1.2 trillion IDR, is approximately the size of the 2005 BLT cash transfer program. In the space of individual policies (cash *or* in-kind interventions) the welfare gain generated by the cash transfer grows fastest with the budget, and cash becomes the optimal policy at a budget of just over 200 billion IDR. Nonlinear kerosene pricing is only preferable to cash for the smallest sized programs. Intuitively, this happens because as the policy budget grows, the cutoff k for the low fuel price rises, and the high price p_2 falls, making cheap fuel available to households with high consumption levels as well.

The first best policy, which combines a BLT-targeted cash transfer and a free nonlinear fuel policy (plotted in dashed orange) is preferred across all policy budget sizes. Below a budget of 600 billion IDR, the second best policy (in dashed light blue) combines nonlinear kerosene pricing with a lump sum transfer. Under this policy, and at all levels of the total budget, all spending is optimally allocated towards the lump sum transfer with a free nonlinear kerosene price implemented simultaneously. Since the lump sum transfer is distribution-neutral, and the welfare gains of a free nonlinear kerosene subsidy don't grow with the the policy budget, the pure targeted cash transfer (solid orange) eventually becomes the second best policy. This occurs at a total policy budget of 600 billion IDR.

5.5 Comparative Statics

5.5.1 Targeting Information Set

The observables available to the Indonesian government for targeting – household member demographic characteristics and housing characteristics – are common across proxy means tested transfer programs worldwide, now and in 2005. Appendix Table A1 summarizes large peer transfer programs in other countries and the targeting observables used. To explore the role of the targeting information set in determining optimal redistributional policy, we add welfare results for two alternative information sets. The first is a more primitive and low-cost set of targeting observables, comprised of just two variables: housing ownership status (own, lease, rent, etc.) and household floor area. The second is an aggregated approach to targeting which assigns cash transfers at the village level to villages with the lowest mean household per capita consumption levels. Rather than requiring a population targeting census to collect observables for each household, this approach requires estimates of mean household consumption by village. It can therefore be drawn from a population sub-sample survey.

In Appendix Figure A7 we show how these alternative information sets affect the performance of the targeted cash transfer relative to nonlinear fuel pricing, at policy budgets of 200 billion IDR. The first and last set of bars replicate results from Figure 5, plotting the welfare gain under a BLT targeted cash transfer and the optimal nonlinear fuel subsidy. The second set of bars plots welfare under a cash transfer targeted with the restricted information set of dwelling characteristics, and the third set of bars plots welfare under the village targeting approach. Village targeting modestly increases the performance of the cash transfer, while the restricted information set reduces welfare by 23% relative to the BLT cash transfer. However, even with such a small information set, this cash transfer generates over two times the welfare gain of nonlinear gasoline subsidy, underscoring the importance of applying in-kind policies to the right consumption good.

5.5.2 Baseline Prices

While the fuel price reforms of 2005 moved gasoline prices up to their full international price, kerosene remained heavily subsidized at 2,000 IDR/liter compared to a Singapore spot price of 4,600 IDR/liter. We explore the welfare effects of introducing redistributional policy on a baseline of full, global fuel prices, to ask whether a new fuel subsidy could outperform a targeted cash approach. Rather than using the 2006 benchmark for policy interventions, we use international prices as the benchmark. This means that there is no budget-neutral kerosene policy available (we do not discuss taxation in this Subsection).

From an unsubsidized baseline, introducing a targeted cash transfer generates a larger welfare gain than nonlinear fuel pricing under any budget. We plot the welfare gain generated by each individual policy against the policy budget in Appendix Figure A8, and report estimates in Table A2. The nonlinear gasoline subsidy generates the least welfare among policy alternatives, while the pure BLT cash transfer generates the most. There is no combined BLT cash transfer and nonlinear fuel subsidy program that outperforms the pure targeted cash transfer, that is, the optimal budget share allocated towards cash is 1. This is consistent with findings under the 2006 benchmark – in both cases, optimal combined interventions allocate all spending towards cash. The second ranked policies are nonlinear kerosene pricing, and combined nonlinear fuel pricing with a lump sum cash transfer, all of which generate, on average, 68% of the welfare gain generated by the targeted cash transfer.

6 Conclusion

Limited information reduces the effectiveness of targeted cash transfer programs worldwide for assisting low-income households with living costs. In-kind transfer systems are pervasive, especially in energy markets, but are often not well-targeted to low income households. Recent theoretical work formalizes this policy design problem, characterizing how the tradeoff between cash and in-kind redistribution depends on household preferences and observable characteristics. We are the first to take these insights to the data, investigating the potential for progressive nonlinear fuel subsidies in Indonesia to outperform targeted cash transfers.

While nonlinear fuel subsidies are more progressive than the linear status quo, they rarely outperform targeted cash transfers. With a targeting information set standard for many low income countries, cash is favored for most levels of the policy budget. The welfare gains generated by nonlinear fuel pricing are less scalable – as larger budgets are directed towards them, fuel becomes more heavily subsidized for all consumers and is less progressively targeted. When there are opportunities for budget-neutral nonlinear fuel policies, or fuel policies involving taxation, the best policy combines these with targeted cash transfers.

The merits of in-kind mechanisms depends on the relevant consumption good. Kerosene mechanisms vastly outperform gasoline mechanisms due to the higher levels of kerosene consumption among low income households. Under our model, nonlinear commodity pricing offers benefits to the extent that consumption of the commodity offers distinct information over observable characteristics available for assigning a cash transfer. Other consumption goods may provide more appealing candidates for in-kind mechanisms, in this setting and others.

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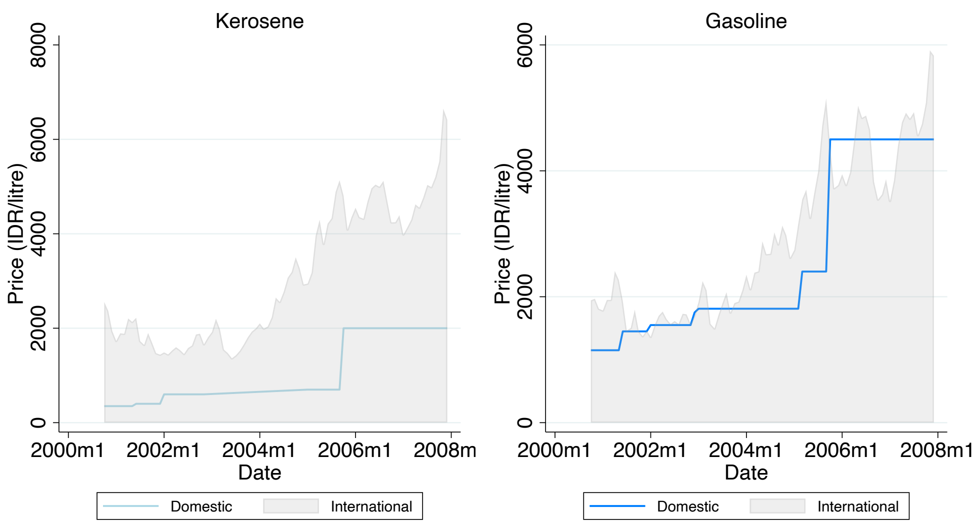
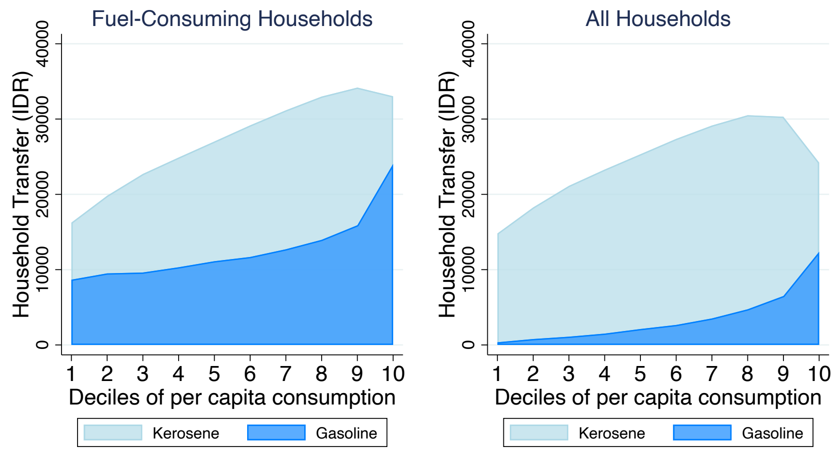
Figures

Figure 1. Subsidy Prices and Crude Prices



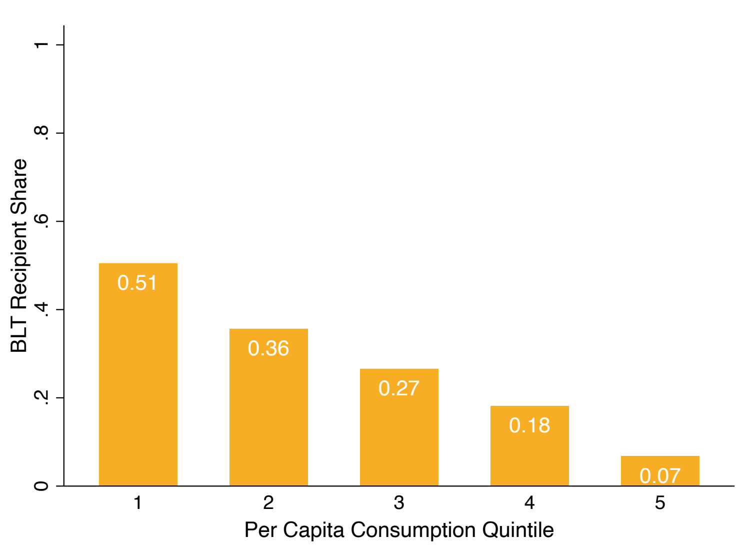
Notes: Figure plots Indonesian domestic and international prices of kerosene and gasoline over time, in IDR per liter. International prices reflect Singapore spot prices, and domestic prices are the official national fuel prices at which the state owned enterprise, Pertamina, sells. Reforms to the domestic prices in October 2005 generated a large shock to consumers.

Figure 2. Avg Household Subsidy Transfer vs. Household Total Per Capita Consumption



Notes: Figure displays the average implied transfer from fuel subsidization within each decile of per capita households total consumption, on the left for households consuming kerosene and gasoline, respectively, an on the right across all households. Specifically we compute Y as the average of: fuel quantity × (global price - national price).

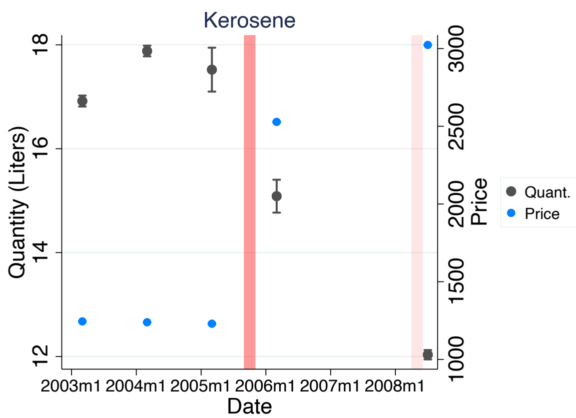
Figure 3. Incidence of BLT



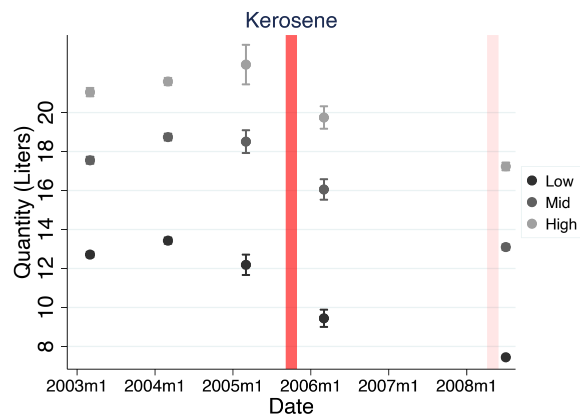
Notes: Figure plots the share of households in each quintile of total per capita consumption who were assigned as recipients of the BLT cash transfer, as recorded in the BLT implementation survey.

Figure 4. Fuel Quantities over Time

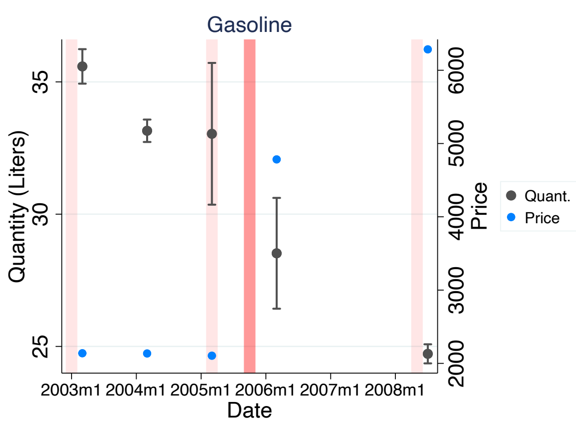
(a) Kerosene Sample Means and Prices



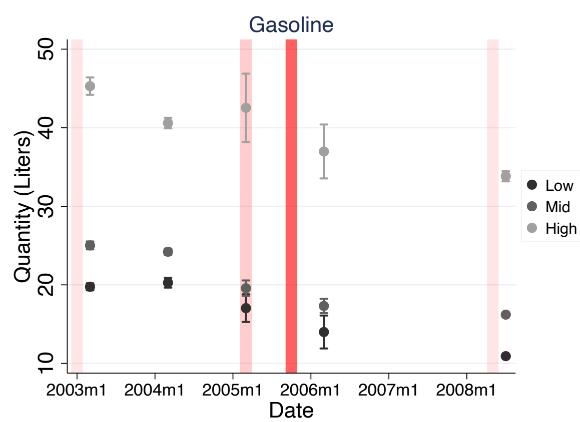
(b) Kerosene Means by Income Tercile



(c) Gasoline Sample Means and Prices

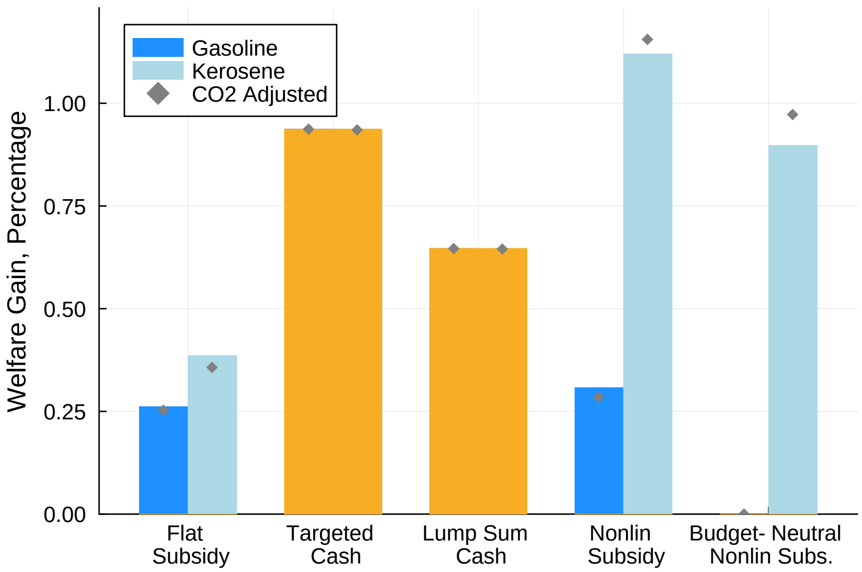


(d) Gasoline Means by Income Tercile



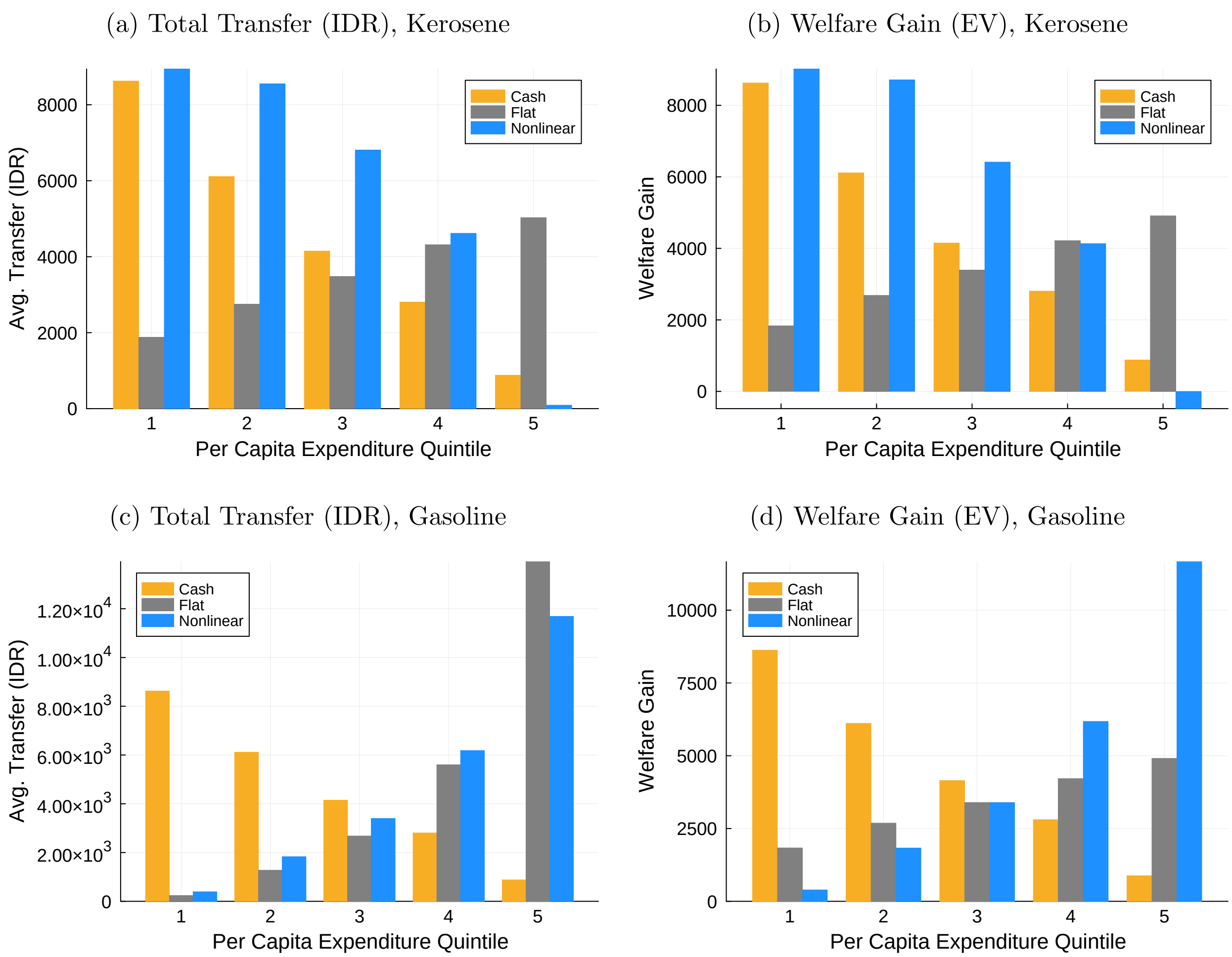
Notes: Figure displays mean fuel quantities and standard errors of the mean consumed by households in each Susenas survey wave. Panel (a) and (c) plot means across the entire sample for kerosene and gasoline, respectively, and display prices over the same time periods. Panels (b) and (d) display mean quantities within each tercile of per capita total household consumption. Dark red vertical lines denote the timing of the large October 2005 national price increases, and light red vertical lines denote the timing of other price increases.

Figure 5. Welfare Gain By Policy



Notes: Figure plots the welfare gain, or equivalent variation, associated with introducing each policy. Welfare gains are reported as a percentage of baseline welfare. All policies have a total budget of 200 billion IDR, with the exception of the Budget-Neutral Nonlinear Subsidy policy. The 200 billion IDR budget represents an additional spending on top of any existing subsidies present in 2006. Fuel policies are in shades of blue and cash policies are in orange. The Flat Subsidy policy is a reduced, linear price of fuel. The Targeted Cash policy represents a targeted cash transfer, assigned using the actual targeting vector of the 2005 BLT program. The Lump Sum Cash transfer is an equal-sized payment to all households in the population. The Nonlinear Subsidy policies introduce two-part tariffs with the 200 billion IDR budget. Finally, Budget-Neutral Nonlinear Subsidy introduces a two-part tariff to kerosene, which is budget-neutral because initial units are offered at a low price, and subsequent units are marked up above 2006 prices. Values plotted in gray adjust for changes in the size of global climate externalities associated with each policy, as measured by the social cost of carbon.

Figure 6. Incidence of Policies, in IDR and Equivalent Variation



(a) Total Transfer (IDR), Kerosene

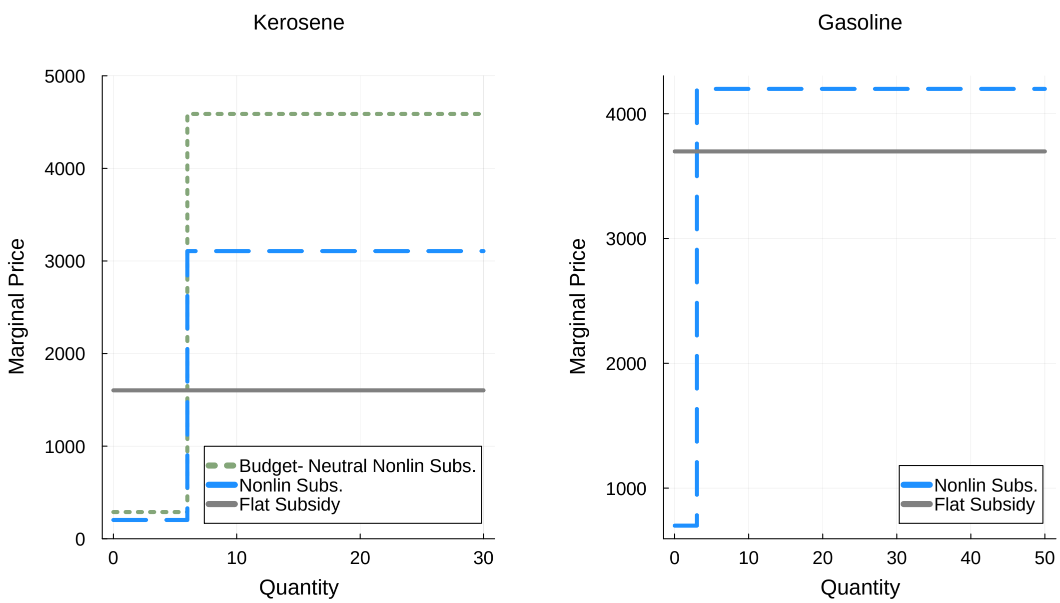
(b) Welfare Gain (EV), Kerosene

(c) Total Transfer (IDR), Gasoline

(d) Welfare Gain (EV), Gasoline

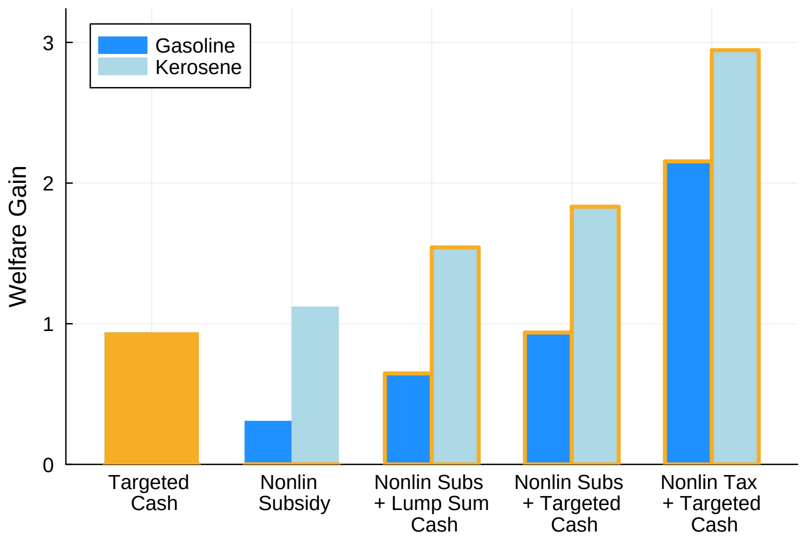
Notes: This figure plots the average household transfer and welfare gain generated by the BLT targeted cash transfer, flat subsidy, and nonlinear fuel subsidy policies for households within each quintile of the households per capita total consumption distribution. Panels (a) and (c) plot the mean of the implied transfer (in IDR) generated by each policy within each quintile. Panels (b) and (d) value the transfer in equivalent variation, counting the mean welfare within each quintile in utils. All policies have a total budget of 200 billion IDR and correspond to the policies plotted in Figures 5 and 6.

Figure 7. Nonlinear Price Policies



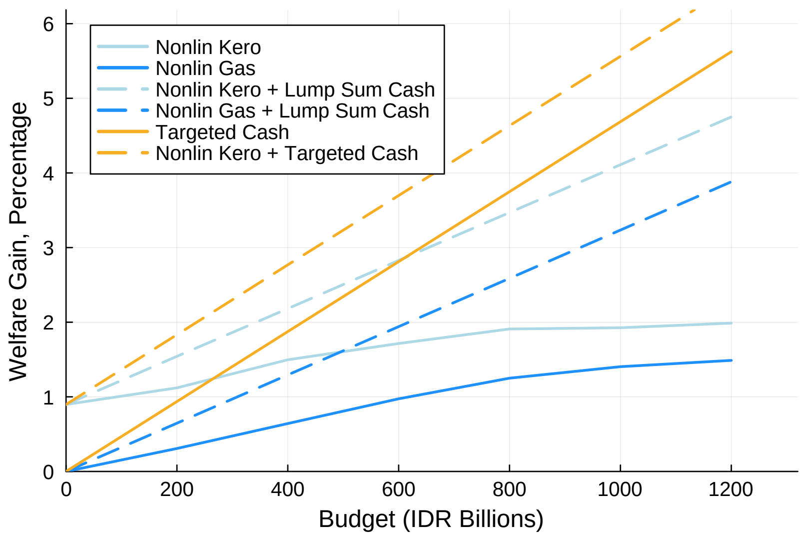
Notes: Figure shows the linear and nonlinear price schedules associated with the Flat Subsidy, Budget-Neutral Nonlinear Subsidy, and Nonlinear Subsidy policies underlying Figure 5, plotted as a function of quantity.

Figure 8. Welfare Gain By Policy, with Combined Interventions



Notes: Figure compares the welfare gain generated by the separate cash and in-kind interventions of Figure 5 (first two sets of bars) with the welfare gain generated by combined interventions featuring both fuel subsidies and cash transfers (last three sets of bars). The welfare gain is reported as a percentage of baseline welfare. Combined interventions are denoted by orange borders. The first combined intervention, Nonlinear Subsidy + Lump Sum Cash, optimally combines nonlinear fuel subsidies with an untargeted lump payment to all households in the population. The Nonlinear Subsidy + Targeted Cash policy optimally combines nonlinear fuel subsidies with the targeted cash transfer. Finally, the Nonlinear Tax + Targeted Cash policy allows for fuel prices to rise above international market prices and generate revenue with which to increase the program budget. Estimates associated with the combined interventions are displayed in Table 2 (policies without taxation) and Table A3 (policies with taxation). All policies have a total budget of 200 billion IDR.

Figure 9. Welfare Gain Against Budget, by Policy



Notes: Figure displays the total welfare gain as a percentage of baseline weflare generated by each policy against the size of the policy budget. Welfare increases with the budget by construction as the size of the transfer to households increases. The figure shows how the ranking of policies changes depending on the size of the reform. Solid lines plot the welfare gains generated by single interventions, either cash or in-kind. Dotted lines plot the welfare gains generated by combined interventions. All estimates associated with each policy are reported in Table 3.

Tables

Table 1. Demand Model Estimates

	(1) Kerosene	(2) Gasoline
Tercile=1 × Log(Price)	-0.351	-0.111
	(0.0202)	(0.0231)
Tercile=2 × Log(Price)	-0.319	-0.130
	(0.0201)	(0.0227)
Tercile=3 × Log(Price)	-0.309	-0.140
	(0.0202)	(0.0227)
Log(Income)	0.470	0.663
	(0.0236)	(0.0288)
Subdistrict FE	Yes	Yes
BLT Control	Yes	Yes
Observations	13670	4853

Notes: Table reports the estimates of our log-log demand function for kerosene and gasoline. Subdistrict fixed effects implement the instrument, conditioning identifying price variation on temporal changes within subdistrict due to changes in the official price of fuel. Three price elasticities are estimated – one for each tercile of the per capita total household consumption distribution. Data come from the 2005 and 2006 waves of the Susenas household panel.

Table 2. Combined Interventions, 200 billion IDR Budget

	Kerosene				Gasoline			
α	p_1	p_2	k	Welfare gain	p_1	p_2	k	Welfare gain
Panel A. Nonlinear subsidy with **lump sum** cash transfer								
0	201	3109	6	1.12	701	4199	3	.31
.2	205	3377	6	1.21	3004	4199	6	.37
.4	206	3677	6	1.3	3559	4199	6	.43
.6	201	4022	6	1.41	4024	4200	3	.5
.8	201	4391	6	1.51	4339	4339	3	.57
1	292	4584	6	1.54	4499	4499	15	.65
Panel B. Nonlinear subsidy with **targeted** cash transfer								
0	203	3106	6	1.12	2448	4199	6	.31
.2	203	3380	6	1.27	1807	4199	3	.43
.4	203	3684	6	1.42	3559	4199	6	.55
.6	201	4024	6	1.58	4025	4200	3	.67
.8	203	4391	6	1.74	4339	4339	9	.8
1	294	4584	6	1.83	4500	4500	9	.94

Notes: Table reports estimated optimal fuel policies and their corresponding welfare gain for combined interventions involving fuel subsidies and cash transfers. Panel A displays estimates for combinations involving untargeted lump sum transfers to all households in the population, display results across values of α, which denotes the share of the total policy budget assigned to the cash transfer versus the fuel subsidy. Panel B reports the same estimates for combinations of fuel subsidies and targeted cash transfers, which are targeted according to the 2005 BLT program recipient vector. We report the total welfare gain as a percentage of baseline welfare.

Table 3. Optimal Policies for each Total Budget Value

	Kerosene				Gasoline			
Budget	p_1	p_2	k	Welfare gain	p_1	p_2	k	Welfare gain
Panel A. Nonlinear subsidy								
200	201	3109	6	1.12	2449	4199	6	.31
400	355	4464	9	1.49	1184	4198	9	.64
600	200	2478	9	1.72	565	4176	12	.97
800	201	4239	12	1.91	306	3863	15	1.25
1000	236	4340	15	1.92	354	4145	21	1.4
1200	200	1639	18	1.99	301	1655	24	1.49
Panel B. Nonlinear subsidy with lump sum cash transfer								
200	301	4562	6	1.53	4200			.65
400	292	4588	6	2.18	4200			1.29
600	292	4591	6	2.83	4200			1.94
800	294	4589	6	3.47	4200			2.59
1000	301	4578	6	4.11	4200			3.23
1200	301	4580	6	4.75	4200			3.88
Panel C. BLT cash transfer								
200	2000			.94	4200			.94
400	2000			1.87	4200			1.87
600	2000			2.81	4200			2.81
800	2000			3.75	4200			3.75
1000	2000			4.69	4200			4.69
1200	2000			5.62	4200			5.62
Panel D. BLT cash transfer with nonlinear subsidy								
200	291	4590	6	1.83	4200			.94
400	291	4597	6	2.77	4200			1.87
600	296	4591	6	3.7	4200			2.81
800	308	4569	6	4.63	4200			3.75
1000	302	4587	6	5.56	4200			4.69
1200	301	4592	6	6.5	4200			5.62

Notes: Table summarizes the policies and corresponding welfare gain by counterfactual, across varying total policy budget sizes. Budget values are in billions of IDR. Panels A and C report values for single policies – nonlinear subsidies and the targeted BLT cash transfer. Panels B and D report values for combined interventions. For combined interventions involving gasoline subsidies, all of the budget is optimally allocated to the cash transfer, and the single baseline fuel price is reported, listing linear prices under p_1. We report the total welfare gain as a percentage of baseline welfare.

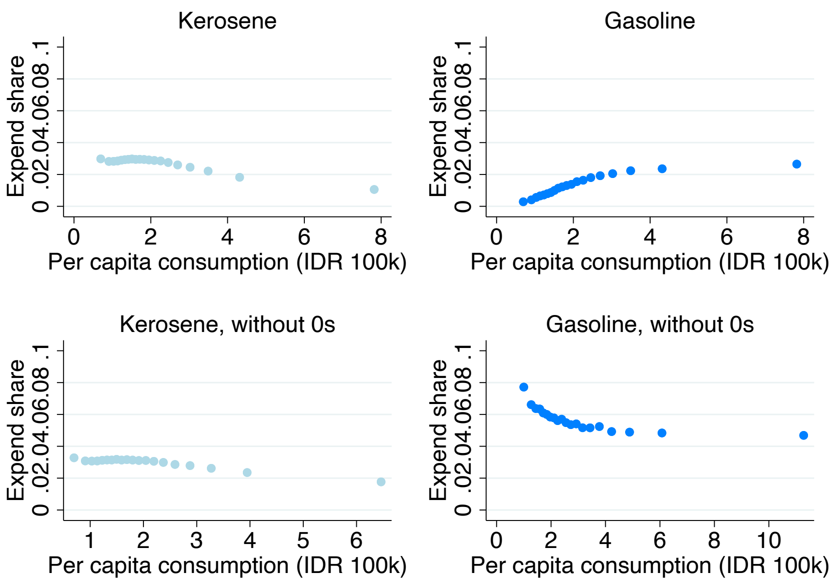
Supplemental Appendix for:

Redistribution with Limited Information: Fuel Subsidies and Cash Transfers in Indonesia

Johanna Rayl and Budy Resosudarmo

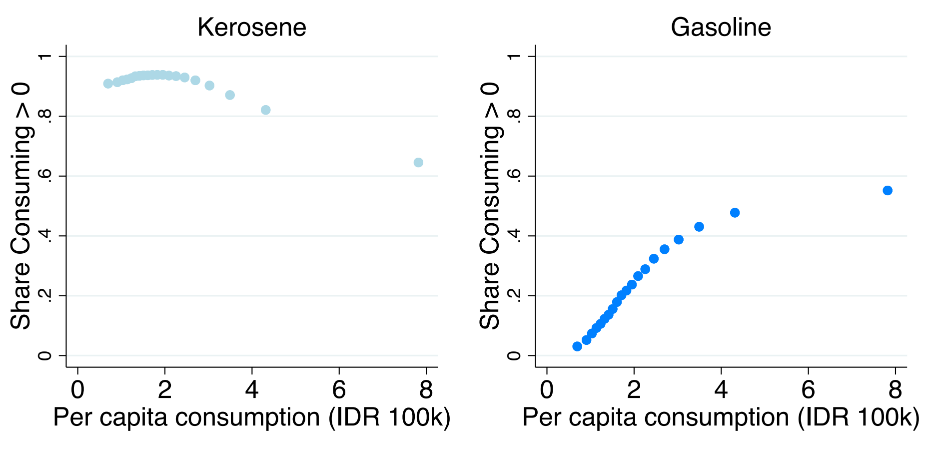
A Supplemental Figures and Tables

Appendix Figure A1. Fuel Expenditure Shares vs. Household Total Per Capita Consumption



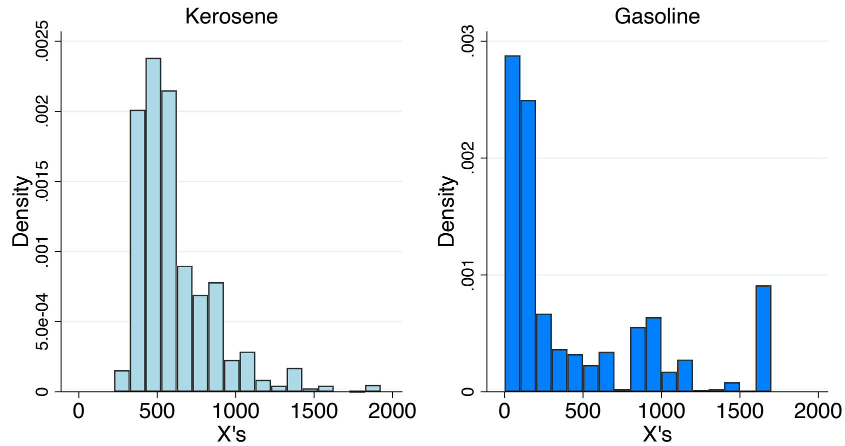
Notes: Figures display the share of total household expenditure share allocated to kerosene and gasoline, binscattered against total (across all consumption categories surveyed) per capita household consumption. Data are from the 2003 and 2004 Susenas cross-sectional survey waves, each of around 220,000 households. Row 1 includes all households, and Row 2 excludes households who consume 0 of kerosene and gasoline, respectively.

Appendix Figure A2. Share of Households Consuming Fuels vs. Household Total Per Capita Consumption



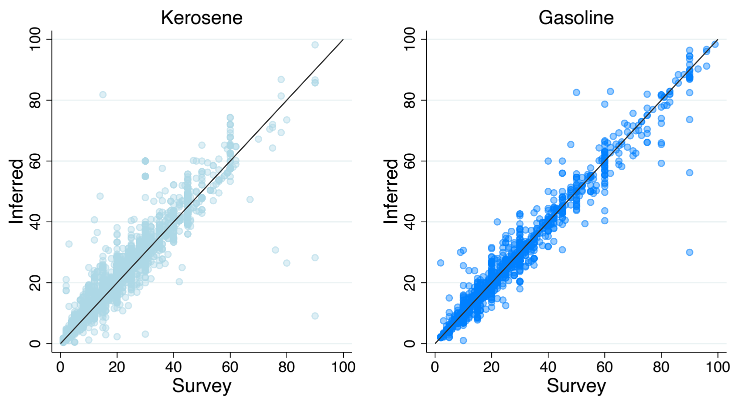
Notes: Figure plots a binscatter of a household indicator for consuming each fuel against household total per capita consumption. The left panel displays estimates for kerosene, and the right panel for gasoline.

Appendix Figure A3. Subdistrict trade costs



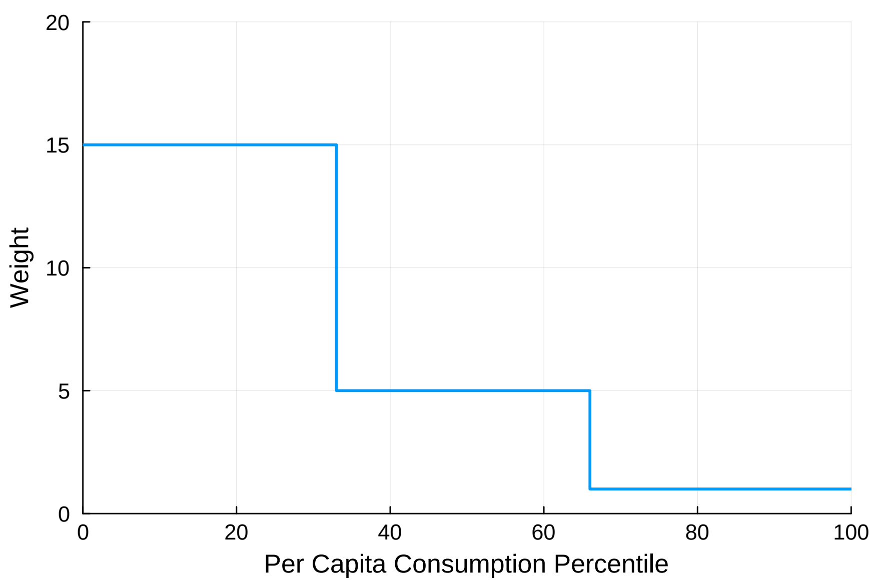
Notes: Figure plots the density of our estimates of x_d, subdistrict trade costs. The left plot reports this density for the kerosene market, and the right plot for the gasoline market.

Appendix Figure A4. Estimated versus Survey Reported Quantities, Gasoline



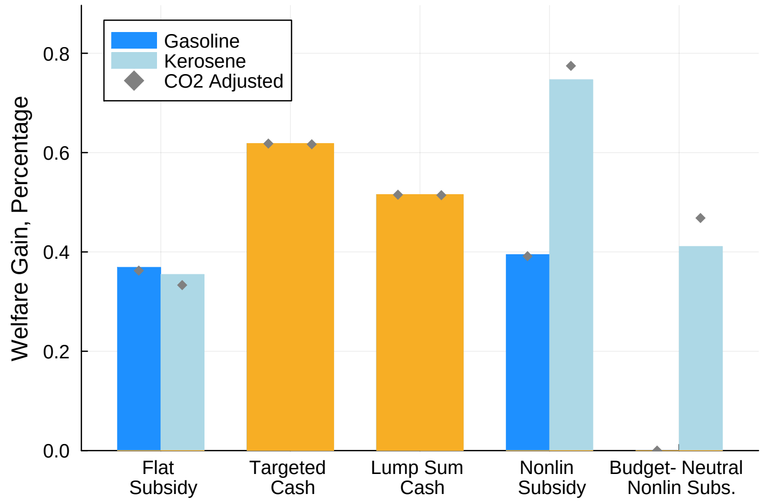
Notes: Figure plots inferred household fuel quantities consumed on the Y axis against actual household fuel quantities reported in the 2005 survey on the X axis, to validate the inference method described in Section 4.1 that we employ to estimate quantities in years where only expenditure is available. Fuel quantity records are available in the 2005 wave of the household panel, but not in 2006.

Appendix Figure A5. Welfare Weight Function



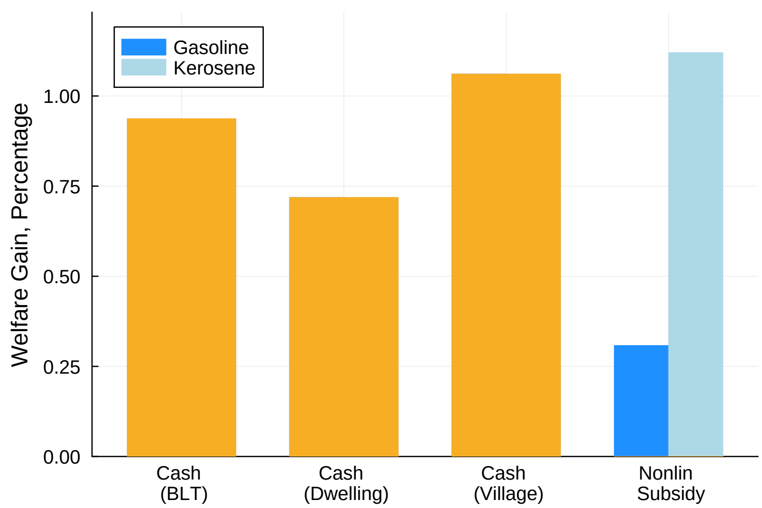
Notes: Figure displays the welfare weight function we assume for the planner, plotting assigned weight against the percentile of household total per capita consumption, which decreases in a household's total per capita consumption. Under this step function, which assigns a high uniform weight to the poorest 30% of households, a planner designing a targeted cash transfer to maximize weighted welfare will (attempt to) assign a uniform payment to the poorest 30%, which replicates the 2005 program.

Appendix Figure A6. Welfare Gain By Policy, Marginal Utility Welfare Weights



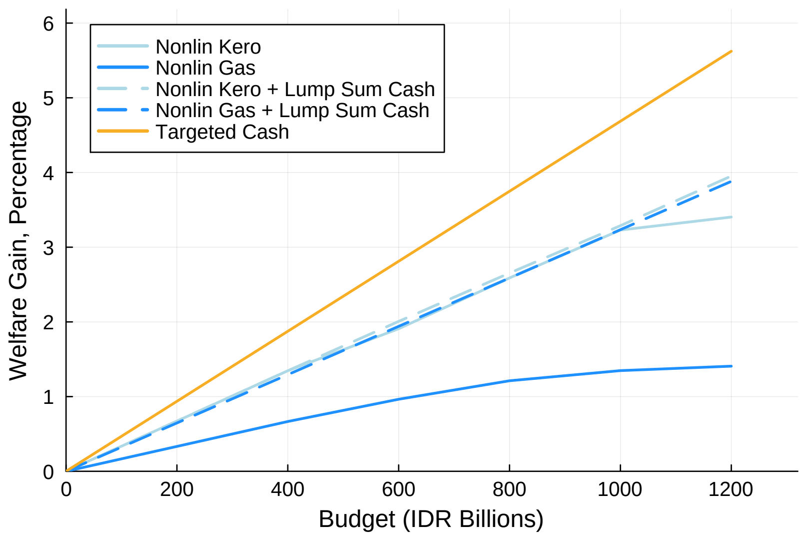
Notes: Figure plots the welfare gain, as a percentage of baseline welfare, associated with a range of counterfactual policies under our alternative welfare weight specification. Alternative welfare weights are a household's marginal utility of consumption under a CRRA utility function and pre-policy consumption levels. All policies have a total budget of 200 billion IDR, with the exception of the Free NL Subs policy. The alternative welfare weight specification is described with more detail in Appendix Section D.

Appendix Figure A7. Welfare Gain by Policy, with Alternative Targeting Info Sets



Notes: Figure displays the welfare gains associated with multiple policies, each of total budget 200 billion IDR. The first three sets of bars display results for cash transfer programs, each featuring a different information set for targeting the cash transfer. The first bars display results from a cash transfer targeted using the BLT targeting proxy means model. In bars two and three, we display alternative cash transfer programs. The second set of bars uses a reduced set of predictor "proxies" relative to the BLT program. The third set of bars uses mean household consumption within a village to assign a village-level transfer.

Appendix Figure A8. Welfare Gain Against Budget, by Policy, Global Baseline Prices



Notes: Figure plots the total welfare gain generated by each policy against the size of the policy budget, for the case where policies are introduced on top of a baseline of no fuel subsidies, rather than a baseline of 2006 fuel prices (as in our primary results). The figure includes individual policies, BLT targeted cash transfer, nonlinear kerosene subsidy, and nonlinear gasoline subsidy, in sold lines. Combined interventions plotted are combinations of nonlinear fuel subsidies and untargeted lump sum transfers. The combined BLT cash transfer and nonlinear fuel subsidy lines are omitted, as the optimal combined policy assigns all dollars to the cash transfer and leaves fuel prices untouched.

Appendix Table A1. Summary of Proxy Means Tests and Proxies Used in Selected Countries

Country	Program	Key Proxies Used
Colombia	Familias en Acción	Dwelling characteristics, household size, demographics of household head
Ecuador	Bono de Desarrollo Humano	Dwelling characteristics and water access, education level of household members, school attendance of children
India	Below Poverty Line	Dwelling characteristics, asset ownership, occupation of household members, education of household members
Kenya	Hunger Safety Net	Community targeting + PMT (dwelling characteristics, asset ownership, member occupations)
Mexico	Oportunidades/Prospera	Dwelling characteristics, asset ownership, education of household head
Pakistan	Benazir Income Support Program (BISP)	Asset ownership, housing conditions, education, household demographics
Peru	Juntos	PMT (Dwelling characteristics, demographics) + Community validation
Philippines	Pantawid (4Ps)	Dwelling characteristics, asset ownership, member demographics

Notes: Table displays selected, large targeted cash transfer programs worldwide, all of which employ proxy means tests for targeting. The third column summarizes the categories of household observables used in the proxy means test to predict income, poverty, or wealth. Typical dwelling characteristics used include material of walls and roof, and access to water and sanitation. See Kidd and Athias (2019) for an evaluation of proxy mean test predictive power in many of these programs.

Appendix Table A2. Optimal Policies for each Total Budget Value, Global Baseline Prices

	Kerosene				Gasoline			
Budget	p_1	p_2	k	Welfare gain	p_1	p_2	k	Welfare gain
Panel A. Nonlinear subsidy								
200	2794	4597	3	.67	1428	4199	6	.33
400	987	4596	3	1.35	504	4197	9	.67
600	1824	4562	6	1.91	325	3825	12	.96
800	932	4589	6	2.59	430	4177	18	1.21
1000	207	4266	6	3.23	303	2798	21	1.35
1200	203	2793	6	3.4	300	835	24	1.41
Panel B. Nonlinear subsidy with lump sum cash transfer								
200	2793	4597	3	.67	4200			.58
400	988	4596	3	1.35	4200			1.17
600	260	4599	3	2.01	4200			1.75
800	265	4596	3	2.65	4200			2.34
1000	986	4597	3	3.29	4200			2.92
1200	244	4581	6	3.95	4200			3.5
Panel C. BLT cash transfer								
200	4600			.94	4200			.94
400	4600			1.87	4200			1.87
600	4600			2.81	4200			2.81
800	4600			3.75	4200			3.75
1000	4600			4.69	4200			4.69
1200	4600			5.62	4200			5.62

Notes: Table summarizes the policies and corresponding welfare gain by counterfactual, across varying total policy budget sizes, in the case where policies are introduced on top of a baseline of no fuel subsidies rather than a baseline of 2006 fuel prices. Budget values are in billions of IDR. Panels A and C report values for single policies – nonlinear subsidies and the targeted BLT cash transfer. Panels B and D report values for combined interventions. We report the total welfare gain as a percentage of baseline welfare.

Appendix Table A3. Tax and Transfer Interventions, 200 billion IDR Budget

Tax Rate	p_1	p_2	k	Cash Budget (billion IDR)	Welfare gain
Panel A. Kerosene					
0	1436	4600	3	1146.99	2.67
.13	471	5175	3	1255.42	2.8
.25	2524	5750	6	1240.96	2.79
.38	2344	6325	6	1284.34	2.87
.5	2185	6900	6	1320.48	2.94
Panel B. Gasoline					
.07	4500	4500	3	200	.94
.18	4451	4950	3	293.98	1.25
.29	4499	5400	3	380.72	1.56
.39	4452	5850	3	467.47	1.86
.5	4456	6300	3	554.22	2.15

Notes: Table reports welfare gains associated with combined interventions involving fuel taxation. We estimate optimal policies for a range of tax rates between 0 and 50% relative to global prices. Fuel sold at price p_2 is taxed (at the given tax rate), while the first k units of fuel remain subsidized at price p_1. Revenue generated by taxing fuel is added to the initial cash policy budget of 200 billion IDR, increasing the budget to the size of the values reported in the fourth column. We report the total welfare gain as a percentage of baseline welfare (2006 fuel prices and no cash transfer).

B Data Appendix

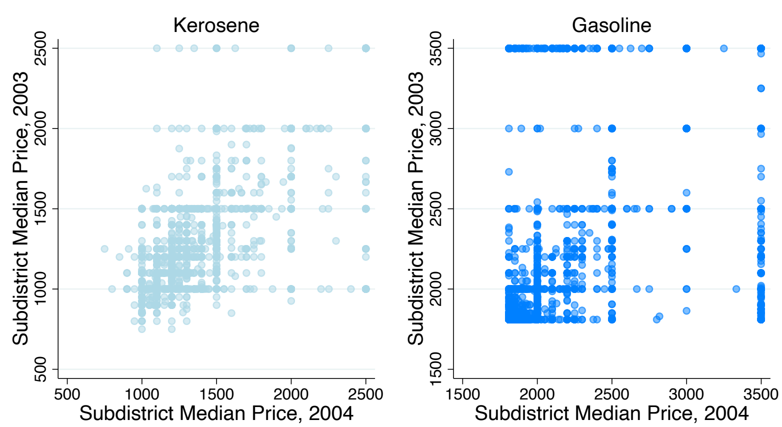
B.1 2005-2007 Susenas Panel

We estimate household preferences and welfare in counterfactual scenarios using the nationally-representative set of 10,000 households surveyed in the 2005-2007 Susenas Panel. We omit 2007 data from analysis entirely. We find that the survey data does not appear to contain monthly consumption values for fuels and many other goods despite their presence in the survey instrument. Consumption values present in the data are orders of magnitude different than the range of values present in all other waves.

B.2 Subdistrict Prices and Fixed Trade Costs

Under our model of intranational fuel supply, we assume local trade costs are fixed over time, meaning that variation in observed local fuel prices over time can only come from changes in the official subsidy price of fuel and from measurement error. Below we plot median subdistrict prices in two years during which the official subsidy price of fuel was fixed to display the magnitude of measurement error we are implicitly assuming. With no measurement error, subdistrict median prices would fall along the 45 degree lines of the panels of Figure B1. The model assumes that remaining variation is attributable to variation in the median of subdistrict prices, resulting from measurement error in household-level unit prices.

Appendix Figure B1. Median Subdistrict Prices, 2003 and 2004



Notes: Figure plots median prices within each subdistrict in 2003 versus 2004. The left panel displays kerosene prices and the right panel displays gasoline prices.

C Estimation Appendix

C.1 Counterfactual Fuel Policies

We estimate optimal two-part nonlinear fuel tariffs using a nested algorithm to search for parameters p_1, p_2, and k. In an outer loop, we guess a value of the cutoff k. Given the guess of k, we use nonlinear optimization in an inner loop to find the value of p_1 which maximizes weighted welfare given the guess of k. Given p_1 and k, p_2 is fixed by the budget constraint. We vary k in the outer loop to find the final policy which maximizes weighted welfare. While the maximization program is the constrained one of Equation 9, we reformulate the problem to reduce the parameter space and implement the budget constraint in an inner loop. We discretize the space of k values over which to search, solving for the optimal p_1 given a value of k along the grid $[3, 6, ..., 21, 24]$. Conditional on k and a guess of p_1, p_2 is pinned down by the budget constraint in an inner loop. In this way, we perform an unconstrained search over values of just p_1, using a simulated annealing algorithm.

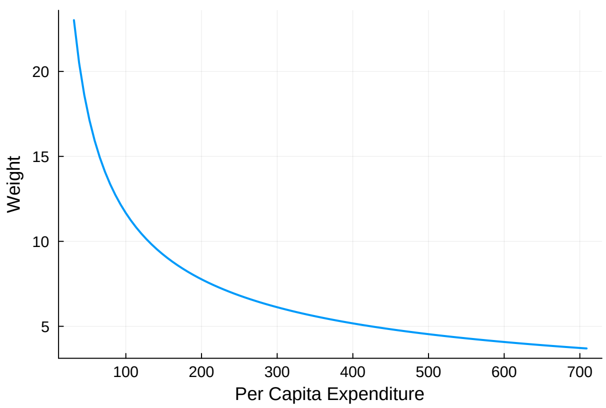
For counterfactuals involving simultaneous taxation and cash transfers, we modify the algorithm. We specify a grid of values of p_2 tax values which fall above global prices, in addition to the grid of k values. We perform an unconstrained search for the optimal value of p_1 given a choice of p_2 and k. For each combination of values of these three fuel policy objects, there is a single value of the cash transfer such that the revenue generated by fuel demanded at this fuel policy and cash transfer value is equal to the aggregate expenditures on cash. We compute this cash transfer value in an inner loop.

D Welfare Weights Robustness

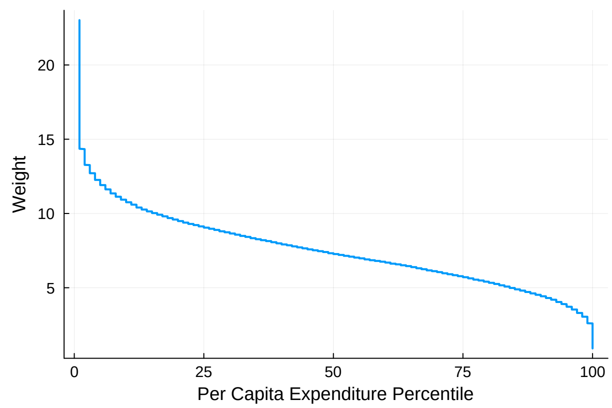
To explore robustness of counterfactuals to alternative welfare weights, we replicate findings with welfare weights based on household marginal utility of income. Under the household preferences in our model, marginal utility of income is $\frac{\partial v(p,y;\theta)}{\partial y} = y^{-\gamma}$. The resulting weight function is plotted below, against income on the left panel and against percentiles of income in the Indonesian income distribution on the right panel for ease of comparison with our baseline welfare weight function.

Appendix Figure C1. Alternative Welfare Weights

(a) Against Household Per Capita Consumption



(b) Against Percentiles of Household Per Capita Consumption



Notes: Figure shows the welfare weights function we examine for robustness, plotted against household per capita total consumption. The left plot displays weights against consumption, while the right plot displays weights against percentiles of consumption.