The Effect of Kerosene Price on Children's Time Allocation Decisions: Evidence from India

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Abstract

This paper studies the effect of kerosene price on the time allocation decisions of children under the age of 15 in Indian households. Because kerosene and biomass fuel are often used as substitutes, an increase in kerosene price may lead to lower demand for kerosene and higher demand for biomass fuel, which must be collected by members of the household. I develop a theoretical model of household utility that formalizes the main mechanisms that affect girls' and boys' time allocation between education and fuel collection, and discuss the parameters that influence the marginal effect of price on education for girls relative to boys. I instrument for kerosene price using lagged kerosene price and use a TSLS strategy to empirically test the effect of price on time allocation. I find that an increase in price results in an increase in fuel collection time for children, a decrease in water collection time for children, but no change in time spent in school. Parents compensate by increasing their water collection time. These results indicate that households are able to mitigate adverse effects on children's schooling time in response to a tighter budget constraint. These time reallocation decisions give insight into how children's education and unpaid labor time may be affected by the Indian government's recent push towards reducing its subsidies for kerosene, causing prices to increase.

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1 Introduction

In many households in developing countries, material well-being depends not only on the time members spend working for a wage in the market, but also on the time members spend doing unpaid labor for household production activities. For example, in India many families collect their own drinking water and cooking fuel rather than purchasing these goods on the market (World Health Organization, 2016). The time allocation decisions of these households - which members collect fuel and water - is often influenced by gender. The gender differences in intra-household time allocation are well documented, with an emphasis on the time allocation decisions of adult women across paid market work, unpaid household work, and work on family enterprises (Redman, 1980; Sharp, Ciscel and Heath, 1998; Gimenez-Nadal and Sevilla 2012; Eswaran, Ramaswami and Wadhwa 2013). A smaller but equally important body of literature examines how the time allocation decisions of children respond to economic shocks. Empirical analysis of how households substitute children's time between unpaid production activities and human capital acquisition activities is important for understanding how policies that affect intra-household time decisions can also influence child welfare.

An important economic shock that may impact the time allocation decisions of children in poor households is a change in price of market based fuel. In particular, the Indian government has heavily subsidized and promoted the use of kerosene for heating and cooking as a cleaner alternative to hazardous biomass fuels that members must spend time collecting, like firewood, animal dung, and crop residue. Thus, it is a widely purchased commodity that theoretically affects the household's fuel collection time, assuming that households that purchase more kerosene will need to spend less time collecting biomass fuel. In developing countries, and in India in particular, women and girls spend a large amount of time collecting biomass fuel like firewood for cooking, lighting, and heating (WLPGA, 2014). Therefore, a change in kerosene price may have important welfare implications for female children in the household. In this paper, I exploit the variation in kerosene prices across India to determine its effect on the time allocation decisions of children. I ask two research questions. (1) Does an increase in the price of kerosene increase the amount of time children spend collecting biomass fuel each week? (2) If so, where does this extra time come from? Are children substituting away from time spent in school, or from other important household tasks such as collecting drinking water for the household? [1] Does this differ for girls and boys?

Previous papers have examined the effects of three broad categories of economic shocks on children's time allocation decisions. First, many papers look at the effect of employment opportunities. Skoufias (1993) finds that an increase in adult female wages significantly reduces school time for girls in India, and that higher child wages lead to decreased leisure hours for both boys and girls, and increased home production for girls already working at home. Manacorda and Rosati (2007) find that an increase in male adult employment reduces time spent doing market work and increases time spent in school for children in Brazil. Fafchamps and Wahba (2006) find that children in Nepal residing in or near urban centers spend more time in school and less time working overall.

Second, several papers also explore the effect of exogenous income shocks on child labor allocations, with mixed results. Teenage girls are significantly more likely than teenage boys and mothers to increase their participation in housework, decrease their time in income generating activities, and decrease time in school in the event of a negative income shock in the form of a sick infant in the household (Pitt and Rosenzweig, 1990). A positive income shock in the form of a cash transfer may be effective at postponing children's entry into the labor force and protecting children's schooling status in Ecuador, but an income subsidy scheme may increase household production time for both boys and girls in Bangladesh (Edmonds and Schady, 2012; Khan, 2012).

[1] Note that while previous time allocation studies lump all household production activities into one category, my paper distinguishes between fuel collection and water collection, in an effort to observe whether an increase in fuel collection time is substituted away from water collection time. It would be most ideal to look at children's time allocation between fuel collection time, all other household production tasks (including water collection), education, leisure, and paid child labor time separately in order to get a more complete picture of the time reallocation effects of kerosene price. However, a lack of complete data on time spent on other household tasks, leisure, and child labor requires me to look specifically at water. While this is limiting, the effect of kerosene price on water collection can still have important welfare implications. Water collection is one of the most physically demanding household tasks, and is detrimental to children's health, especially compared to food production and child/elderly care, two other common household tasks (WLPGA, 2014). Therefore, although a more complete analysis of all time allocation categories would be more informative, understanding how households allocate time to water still has important child welfare implications.

Finally, a few papers also look at the effect of macro shocks on children's time allocation decisions. Edmonds et al. (2009) find that India's 1991 trade liberalization increased children's schooling and decreased child labor. Schady (2004) finds that the 1988-92 macroeconomic crisis in Peru did not affect attendance rates of children, but caused a significant decline in the faction of children who were employed in the market.

An important determinant that has not yet been explored is the effect of prices of consumer goods that influence household production tasks, particularly the effect of market based fuel on fuel collection time. This research question is particularly policy relevant in India, where the government has recently taken steps to phase out the kerosene subsidy it has provided through its Public Distribution System for decades, causing kerosene price to increase (Chowdhary, 2017). This paper takes the first step towards predicting the effects of this increase in price on children's time allocation outcomes.

Households in India often face a trade-off when it comes to allocating children's time between education and unpaid household production tasks. If a gender bias exists, as is frequently suggested in the literature (Bhalotra and Cochrane, 2010), then this trade-off will be different for sons and daughters. I develop a theoretical model of household utility that formalizes the main mechanisms that affect girls' and boys' time allocation between education and fuel collection, and discuss the parameters that influence the marginal effect of price on education for girls versus boys and the marginal effect of price on water collection for girls versus boys. I then test the model's predictions empirically by using lagged kerosene price as an instrument for current kerosene price in a two stage least squares framework. The instrument is used to reduce simultaneity bias resulting from bribes, a potentially endogenous source of variation in kerosene price. I find that a 1 INR increase in kerosene price increases both girls' and boy's fuel collection time, and that some (but not all) of this fuel collection time is substituted away from water collection for girls and boys. Both parents compensate for this decrease in water collection time by increasing their own water collection time. No statistically significant amount of time is substituted away from time spent in school for both boys and girls. These results suggest that the Indian government's plan to reduce kerosene subsidies may not impact education, as the average household is able to mitigate any adverse effects on school time by substituting away from other activities. However, the lack of an effect of kerosene price on education time should not be interpreted as a lack of any welfare decreasing effect. The unobserved time allocation category beyond fuel collection, water collection, and education time includes categories like leisure, which could be affected by kerosene price and therefore have important welfare implications for children. Future research using more complete data on omitted categories may help complete the time reallocation story for Indian households.

The remainder of this paper is organized into four sections. Section 2 gives background on the determinants of subsidized kerosene price in India and summary statistics, section 3 presents a theoretical model and its implications, section 4 outlines the identification strategy, and section 5 presents the results. Finally, section 6 concludes with a discussion on policy implications and future lines of research.

2 Background on fuel price and use in India

2.1 Kerosene price under the Public Distribution System

For the past seven decades, India's Public Distribution System (PDS) has provided a food safety net to households in India living below the poverty line by distributing essential food grains and fuels such as wheat, rice, sugar, and kerosene at subsidized prices. These items are sold through fair price shops (also known as ration shops), which are established in every state across the country. In 1997, India replaced the PDS with the Targeted Public Distribution System (TPDS) in an effort to channel subsidies towards the most vulnerable households. Beneficiary households under this scheme are divided into three categories: those above the poverty line (APL), who receive a smaller subsidy and therefore pay a higher unit price per good; those below the poverty line (BPL), who receive a larger subsidy and therefore pay a lower unit price per good; and those who are "antyodya anna yojana" (AAY), the poorest of the poor of BPL households who receive the largest subsidy and pay the lowest price (NCAER, 2015). Each of India's twenty-nine state governments are responsible for independently identifying and distributing TPDS cards to BPL, APL, and AAY households. They are also responsible for fixing the final retail price that each type of household will pay for each good after taking the margins for wholesalers/retailers, transportation charges, and local taxes into consideration (GK Today). 72% of Indian families in the India Human Development Survey (IHDS) dataset used in this paper report falling into one of the three TPDS categories and buying their kerosene through ration shops at subsidized prices.

Given the structure of the TPDS system, I expect prices to vary across at most three values within each village, since the transportation and tax costs that influence the final retail prices for APL, BPL, and AAY households should be very similar within each village, particularly smaller villages. However, I see considerable within-village price variation across most villages in the IHDS data. For example, in Jammu and Kashmir, India's northernmost district with relatively geographically small villages, the reported unit price of kerosene in many villages varies between 10 to 20 INR, with more than three unique values. This indicates that there is another source of price variation beyond what is determined by the state government. The other possible source of variation is the corruption endemic to the TPDS system (Chakrabarti et al, 2016). According to an India Corruption Study conducted by Transparency National India in 2012 (the same year the data was collected for this study), 34% of slum-dwelling households report paying an additional bribe to purchase goods at a ration shop. Households report paying a range of 5-800 INR in bribes for PDS goods per month. This suggests that when asked how much they pay for kerosene, households are likely reporting the total unit cost per liter of kerosene, including any bribes paid, in the IHDS data.

Therefore, there are two possible sources that cause variation in ration shop kerosene prices. One source of variation is from the differences in price attributed to different households by their poverty status, determined independently by each state government. This variation is also related to village-level factors (e.g. transportation costs) that influence the state-chosen price. The second is from bribes paid in addition to the subsidized unit price. On average, the reported subsidized prices are lower than the unsubsidized market price. The IHDS dataset indicates that the average subsidized price per liter of kerosene that households report paying is 13.32 INR, compared to the average market price of 19.23 INR. It is important to note that the reported subsidized price is likely higher than the actual price set by the state due to bribes, but it is not possible to determine what percent of the subsidized price can be attributed to bribes as there is no public data on the "true" village level, state-chosen APL, BPL, and AAY prices. These sources of price variation determine the identification strategy I use in section 4.2.

2.2 Summary statistics on fuel use and time allocation

Table 1 shows how households in the IHDS data use five common types of fuel. It is broken down by the percentage of households that use each type of fuel primarily for cooking, heating, lighting, a combination, or not at all. Kerosene is used by 72 percent of households in the IHDS data, primarily for lighting in rural households but also often for cooking, particularly among peri-urban households. Liquefied petroleum gas (LPG) is an alternative market-based fuel, used by about half of the households in the data. Aside from market-based fuels, hazardous biomass fuels like firewood, dung, and crop residue are also widely used, and must be physically collected from the surrounding area by family members.

Table 1: Main purpose of each fuel type (percentage of households)

	kerosene	lpg	firewood	crop residue	dung
Fuel not used	28.20	53.21	28.17	78.80	61.97
Mainly cooking	10.44	39.16	51.09	15.80	31.61
Mainly lighting	42.93	.33	0.38	0.12	0.11
Mainly heating	1.63	.25	2.87	1.85	0.75
Combination	16.79	7.06	17.48	3.43	5.56
Total	100.00	100.00	100.00	100.00	100.00

The IHDS data reflects the gender bias that influences households' time allocation decisions for household production activities. Table 2 shows the total number of minutes per week that women over age 15, men over age 15, girls under age 15, and boys under age 15 spend collecting fuel, collecting water, and going to school. Women and girls spend statistically significantly more time on average collecting both fuel and water than men and boys. However, somewhat surprisingly, girls and boys spend on average the same amount of time in school per week.

Table 2: Average fuel, water, and school time allocation

	Women	Men	Difference
Fuel collection time (min/week)	304.79	249.31	55.48
	(10.43)	(9.42)	(5.93)
N	5,673	3,538	
Water collection time (min/week)	313.87	192.31	121.56
	(2.57)	(2.03)	(2.19)
N	19,937	15,158	
	Girls	Boys	Difference
Fuel collection time (min/week)	322.21	303.87	18.34
	(22.18)	(20.84)	(9.62)
N	924	731	
Water collection time (min/week)	88.49	73.41	15.07
	(1.82)	(1.66)	(1.28)
N	11,028	10,433	
School time (hours/week)	32.44	32.5	0.06
	(.07)	(.07)	(.10)
N	13,387	14,929	

Standard errors in parenthesis. Women and men are defined as household members above age 15, and girls and boys are defined as household members aged 15 or younger.

3 Theoretical model

3.1 A simple utility model

Following Becker (1965), I develop a simple model in which household utility is derived from the consumption of a market good and from the consumption of the human capital production functions of its children, which require time as inputs. Consider a household with preferences over quantities of a composite good $x \in \mathbb{R}_+$, market-based fuel $e \in \mathbb{R}_+$, [2] and household production of human capital Z_1 and $Z_2 \in \mathbb{R}_+$, which correspond to girl's human capital and boy's human capital.

For simplicity, I assume a household has one boy, one girl, and parents who jointly make time allocation decisions for each child. The household's preferences can be represented by a continuous and differentiable utility function:

$$U\big(G(x,e),\ \theta_g * Z_1(T^g_{educ}),\ \theta_b * Z_2(T^b_{educ})\big),$$

where T^g_{educ} and T^b_{educ} are inputs in the human capital production functions, and represent the time the girl and boy spend going to school, studying, or attending tutoring lessons. Because I include all of these measures of human capital acquisition categories, T^g_{educ} and T^b_{educ} do not have upper bounds, as they would if they only measured time spent in school, which logically cannot exceed a certain number of hours per day. I assume $G(x,e)$, Z_1, Z_2 are increasing in their arguments and concave. $\theta_g, \theta_b \geq 0$ are parameters that represent the household's perceived returns to investing in the human capital of the daughter and son respectively.

I base the main model on Gronau's (1977) model of household allocation of time between work in the market, work at home, and leisure, with a few key alterations. I omit leisure from entering the utility function, and break up children's time spent at home between fuel collection (which enters through the time constraints) and going to school, two choice variables I am interested in exploring

[2] Empirically, this market based fuel is kerosene.

empirically. I assume that the marginal rate of substitution between two endogenous variables in different subsets is independent of the quantity of any endogenous variable in any other subset. Therefore, I impose an additive and separable structure on the utility function. The household's optimization problem[3] can be stated as:

$$\max_{x,e,T^g_{educ},T^b_{educ}} \quad G(x,e) + \ \theta_g * Z_1(T^g_{educ}) + \ \theta_b * Z_2(T^b_{educ}) \tag{1}$$

Subject to two time constraints, a constraint on fuel e, and one budget constraint:

$T^g_{total} = T^g_{educ} + T^g_{fuel}$ *Total time girl has*

$T^b_{total} = T^b_{educ} + T^b_{fuel}$ *Total time boy has*

$e = m + \alpha_g * T^g_{fuel} + \alpha_b * T^b_{fuel}$ *Total amount of fuel*

$e \geq \bar{e}$ *Total fuel must meet $\bar{e}$, the minimum amount of fuel needed for survival*

$p_x x + p_m m = I$ *Budget constraint, where I is parents' income.*

The total amount of fuel e is comprised of the amount of market-based fuel the household purchases m, and the total amount of biomass fuel the children collect, given by $\alpha_g * T^g_{fuel} + \alpha_b * T^b_{fuel}$, where $\alpha_g \in \mathbb{R}_+$ and $\alpha_b \in \mathbb{R}_+$ are the rates of fuel collection for the girl and the boy respectively, and T^g_{fuel} and T^b_{fuel} are the amounts of time the girl and the boy spend collecting fuel. The more fuel a household purchases from the market m, the less time its children must spend collecting biomass fuel.

The key exogenous parameter that is tested empirically is p_m, the price of one unit of purchased fuel, which theoretically influences demand for market-based fuel, and therefore the total time children need to collect biomass fuel. For example, if the price of kerosene decreases and causes

[3] I omit a number of important endogenous variables from this model in order to keep the focus on education and to prevent the comparative statics analysis conducted in section 3.2 from becoming computationally too complicated. In reality both parents, particularly the mother, also spends time collecting fuel, a complexity not built into the model. Parents' time working in the market are also endogenous rather than exogenously given through income I. The model is also missing leisure time, and time spent doing paid labor in the market for the girl and the boy. Most importantly, the ideal model would include household production of water, and parents', boy's and girl's water collection time as inputs, since I am interested in testing the effects of kerosene price on water empirically. All of these variables are omitted in order to minimize the number of endogenous variables. This allows me to apply Cramer's rule in the comparative statics analysis in order to derive predictions for the effect of kerosene price on children's education time. See Appendix A for a model that includes water collection.

household demand to increase, children will need to spend less time collecting biomass fuel and parents will have to decide (a) whether the girl or the boy should spend less time collecting fuel and (b) whether the girl or the boy should reallocate the extra time to school. These decisions will be determined by how much the household values the girl's human capital acquisition relative to the boy's, represented by θ_g and θ_b. They are also influenced by the girl's and the boy's fuel collection rates α_g and α_b.

In an Indian setting, it is reasonable to assume that girls' labor in home production tasks like fuel collection is viewed as more valuable than boys'. Although biological conditions suggest sons may be stronger and more able to perform physically demanding tasks, girls are usually considered better substitutes for mothers to perform household production tasks, particularly collecting fuel, which is overwhelmingly done by women and girls (Björkman-Nyqvist, 2013; UNDP, 2011). Therefore, α_g and α_b can be conceptualized more accurately as the household's *perceived* fuel collection rate for girls and boys - the household's perception of which child's household labor is considered more valuable. Thus, I assume $\alpha_g > \alpha_b$.

Conversely, I assume that girls' human capital is viewed as less valuable than boys' human capital by the household. In India, it is common for boys to remain in their natal households into adulthood and after marriage, while girls traditionally leave their households to live with her husband's family. Lacking any kind of pension program or social security at old age, parents often rely on the income brought by sons, and therefore have an economic incentive to allocate more time to boys' education than to girls' (Rosenzweig and Schultz 1982; Shepherd 2008; Rosenblum 2017). Consequently, θ_g and θ_b are influenced by the expected private return to children's education from the parents' perspective. Given the higher private economic benefit of sons relative to daughters, I assume that $\theta_b > \theta_g$.

Like Björkman-Nyqvist's (2013) model, there are four key properties of this model. (1) It is always more optimal for parents to allocate more (or at least as much) of its son's time to education compared to the daughter: $T^b_{educ} \geq T^g_{educ}$. (2) The daughter will engage in human capital acquisition iff the boy is sent to school full time and the daughter has left over time after meeting the household's given fuel collection constraint. (3) The son's education time can only be optimally reduced iff the daughter collects fuel full time and the household's fuel collection constraint has not been met. (4) If both $T^g_{educ} > 0$ and $T^b_{educ} > 0$, then a reduction in parental income I will on the margin reduce the time allocated to the daughter's education.

3.2 Comparative statics

According to the utility model described, a change in the price of market-based fuel p_m will change the amount of time children need to collect biomass fuel and therefore potentially the amount of time they can spend in school. I derive the following expression for $\frac{\partial T^g_{educ}}{\partial p_m}$ from the first order conditions using an implicit functions approach (see Appendix B for the full derivation):

$$\frac{\partial T^g_{educ}}{\partial p_m} = \frac{\underbrace{\alpha_g \theta_b \frac{\partial^2 Z_2}{\partial (T^b_{educ})^2}}_{\text{strictly negative}} \underbrace{\left(\underbrace{\lambda \frac{p_x^2}{p_m^3}}_{\text{strictly negative}} - \underbrace{\frac{\partial^2 G}{\partial x^2}}_{\text{strictly negative}} \right)}_{\text{non-negative}}}{\frac{\partial^2 G}{\partial x^2} \left(-\theta_g \alpha_b^2 \frac{\partial^2 Z_1}{\partial (T^g_{educ})^2} - \alpha_g^2 \theta_b \frac{\partial^2 Z_2}{\partial (T^b_{educ})^2} \right) - \frac{p_x^2}{p_m^2} \theta_b \theta_g \frac{\partial Z_1^2}{\partial (T^g_{educ})^2} * \frac{\partial Z_2^2}{\partial (T^b_{educ})^2}} \leq 0, \tag{2}$$

where λ is the Lagrange multiplier.

Assuming that $G(x, e)$, Z_1, and Z_2 are concave and increasing in their arguments, the sign of the denominator is positive. [4] The negative numerator gives $\frac{\partial T^g_{educ}}{\partial p_m} \leq 0$, indicating that an increase in the price of kerosene should decrease the time the girl in the household spends on education activities, presumably because she must now spend more time collecting fuel.

Note that the numerator is only positive conditional on the following inequality:

[4] The denominator is an expression for the determinant of the bordered Hessian matrix used to check second order conditions. This is satisfied because the expression is positive.

$$\frac{\partial^2 G}{\partial x^2} \leq \lambda \frac{p_x^2}{p_m^3}. \tag{3}$$

Substituting $\lambda = -\frac{\theta_g}{\alpha_g} \partial \frac{Z_1}{\partial T_{educ}^g}$, an expression derived from the first order conditions in Appendix B, into the inequality gives

$$\frac{\partial^2 G}{\partial x^2} \leq -\frac{\theta_g}{\alpha_g} \frac{\partial Z_1}{\partial T_{educ}^g} \frac{p_x^2}{p_m^3}. \tag{4}$$

The concavity of $Z_1(T_{educ}^g)$ and the girl's level of education T_{educ}^g determine whether or not the expression above is a strict inequality or equal to zero. In the case where the inequality is strict, T_{educ}^g is reasonably high, so that $\frac{\partial Z_1}{\partial T_{educ}^g} > 0$, but not enough for the value on the right hand side of inequality 4 to be as small as the value on the left hand side. In this case, equation 2 will be $\frac{\partial T_{educ}^g}{\partial p_m} < 0$, which indicates that an increase in kerosene price strictly reduces the amount of time the girl spends on education for girls with reasonably high levels of education. This is consistent with property 4 of the model: If both $T_{educ}^g > 0$ and $T_{educ}^b > 0$, then a reduction in parental income I will on the margin reduce the time allocated to the daughter's education.

In the case where the expression is equal to 0, the value of $\frac{\partial Z_1}{\partial T_{educ}^g}$ is large enough to offset the magnitude of $\frac{\partial^2 G}{\partial x^2}$. This will be the case if the girl has a level of education, T_{educ}^g, equal to or very close to zero because the marginal return to an additional unit of education will be very large: $\frac{\partial Z_1}{\partial T_{educ}^g} >> 0$, given that Z_1 is increasing in T_{educ}^g with diminishing marginal returns. If this value is large enough to reduce the value on the right hand side of inequality 4 down to the same value as the expression on the left hand side, then equation 2 will be: $\frac{\partial T_{educ}^g}{\partial p_m} = 0$. Economically, this means that for girls with $T_{educ}^g = 0$, an increase in the price of kerosene will result in no change in her education level. This result makes intuitive sense in the context of the model given by equation 1. If a girl is starting with zero education time, then her time has already been allocated fully to fuel collection, and an increase in fuel price creates an additional need for fuel collection that can only be met with the boy's time, which must be substituted away from his education. This is consistent with property 3 of the model: The son's education time can only be optimally reduced iff the daughter collects fuel full time and the household's fuel collection constraint has not been met.

A symmetric set of results holds for the effect of market fuel price on boy's education time:

$$\frac{\partial T^b_{educ}}{\partial p_m} = \frac{\alpha_b \theta_g \frac{\partial^2 Z_1}{\partial (T^g_{educ})^2} \left(\lambda \frac{p_x^2}{p_m^3} - \frac{\partial^2 G}{\partial x^2} \right)}{\frac{\partial^2 G}{\partial x^2} \left(-\theta_g \alpha_b^2 \frac{\partial^2 Z_1}{\partial (T^g_{educ})^2} - \alpha_g^2 \theta_b \frac{\partial^2 Z_2}{\partial (T^b_{educ})^2} \right) - \frac{p_x^2}{p_m^2} \theta_b \theta_g \frac{\partial Z_1^2}{\partial (T^g_{educ})^2} * \frac{\partial Z_2^2}{\partial (T^b_{educ})^2}} \leq 0 \tag{5}$$

The key differences between equation 2 and equation 5 are the first two parameters given in the expression in the numerator. In equation 2 they are α_g and θ_b and in equation 3 they are α_b and θ_g. Given that $\alpha_g > \alpha_b$ and $\theta_b > \theta_g$, it follows that

$$\frac{\partial T^g_{educ}}{\partial p_m} \leq \frac{\partial T^b_{educ}}{\partial p_m}. \tag{6}$$

That is, girls will spend less time on education as a result of an increase in the price of market-based fuel than boys. I test for the signs and sizes of these marginal effects empirically in the next section, using kerosene as the market-based fuel m. In addition, I test whether any of the extra time required to collect fuel as a result of a price increase comes out of time spent collecting water, a household production activity not represented in the theoretical model in order to keep the comparative statics analysis feasible, but one that households realistically undertake.

3.3 A discussion of the hypothesized effect of kerosene price on water collection

Ideally the theoretical model given by equation 1 would include time spent collecting water for girls and boys as variables, and I would conduct a comparative statics analysis similar to the one done in the previous section to develop a hypothesis for the effect of price on water collection.

However, as noted earlier, adding more endogenous time variables makes the comparative statics analysis of the effect of kerosene price on education time more computationally complicated. Consequently, in this section I include a verbal discussion of a formal hypothesis regarding how the price of kerosene affects water collection. Let $\frac{\partial T^s_{water}}{\partial p_m} > 0$ denote the marginal effect of an increase in price on the time the child of gender s spends collecting water. The more complex utility model presented in Appendix A helps motivate the following discussion.

Effect of kerosene price on girl's water collection time

Assume $\frac{\partial T^g_{fuel}}{\partial p_m} > 0$ and $\frac{\partial T^g_{educ}}{\partial p_m} < 0$ (that equation 2 is a strict inequality). Then, given the higher value placed on the girl's household labor relative to the boy's and the lower value place on girl's human capital acquisition relative to boy's, we can expect the following change in water collection time:

$$\frac{\partial T^g_{water}}{\partial p_m} \leq 0. \tag{7}$$

This marginal effect is strictly less than zero if all the time that has been *first* reallocated from the girl's education time to fuel collection is not enough to meet the household's fuel constraint, and extra time is needed from water collection. Otherwise, the marginal effect is zero.

Effect of kerosene price on boy's water collection time

Assume $\frac{\partial T^b_{fuel}}{\partial p_m} > 0$. Then, we can expect the following change in water collection time:

$$\frac{\partial T^b_{water}}{\partial p_m} < 0. \tag{8}$$

This inequality is strictly less than zero because the time used to cover the boy's increased fuel collection time *must* come from the boy's water collection time before it comes from his education, given the high value the household places on the boy's human capital acquisition relative to girls ($\theta_b > \theta_g$) and given the lower value placed on the boy's household labor activities relative to the girl's ($\alpha_b < \alpha_g$).

4 Empirical estimation

4.1 Data and population of interest

I use one year of cross-sectional data from the nationally representative India Human Development Survey (IHDS) collected from mid 2011 to mid 2012 (Desai and Vanneman, 2011-12). It contains data on 42,152 households in 1503 villages and 971 urban neighborhoods across India. I limit my analysis to households that report only buying kerosene at a subsidized price from a ration shop over the last thirty days, which comprise 72 % of the data.

My rational for this restriction is twofold. First, I am interested in only the households that buy the subsidized PDS kerosene rather than market price kerosene because this is the policy-relevant population. The time allocation decisions of these households will be affected as the PDS price of kerosene increases, due to the recent push in 2016 to reduce kerosene subsidies (Chowdhary, 2017). I discuss the policy implications of this in relation to the results of my study in section 6. Second, I find that lagged market price is a weak instrument for the market price of the non-ration shop kerosene, [5] but that the lagged PDS price instrument is strong.

[5] Based on a first stage F statistic < 10.

4.2 Identification strategy

4.2.1 Effect of kerosene price on biomass fuel collection time

To examine how kerosene price influences children's time allocation, I ask two categories of questions: (1) Does an increase in the price of kerosene increase the amount of time children spend collecting fuel each week? (2) If so, where does this extra time come from? Are children substituting away from time spent in school, or from other important household tasks such as collecting drinking water for the household? Does this differ for girls and boys?

The causal model of interest to answer question (1) can be estimated by OLS:

$$FuelCollectionTime_h^s = \beta_0 + \beta_1 KerosenePrice_h + \beta_2 Controls_h + \epsilon_h, \tag{9}$$

where $FuelCollectionTime_h^s$ is the number of minutes per week all children of sex s under age 15 in household h spend collecting biomass fuel. $KerosenePrice_h$ is the ration shop price of one liter of kerosene that household h reports paying, and β_1 is the coefficient of interest. $Controls$ is a vector of control variables.

As discussed in section 2.1, there are two sources of endogenous price variation that must be addressed in the identification strategy. One source of variation is from the differences in price paid by each household according to their poverty status, which is determined by each state government after taking into account margins for wholesalers/retailers, transportation costs, and local taxes. Because a household's poverty status and village level factors may also influence its biomass fuel collection time, the $Controls_h$ vector includes three measures of household wealth: annual income, annual per capita expenditure, and a binary variable for whether the household is above or below the poverty line.[6] I also control for village level factors that could simultaneously influence both transportation costs that lead to price variation as well as conditions that affect the outcome of

[6]The exact measures for how each state government categorizes households as APL, BPL, and AAY is not clear from government reports. Therefore, I include thee possible measures of wealth that should be at the very least correlated with the prices that households pay for subsidized ration shop goods.

interest. These include the quality of village roads, the distance to a paved road that provides access to the village, and whether the household lives in a rural or urban area.

In addition to these variables, the *Controls* vector also includes the number of children of sex s under age 15 in the household, the total number of family members, distance to the nearest ration shop, the number of hours of electricity per day that the household reports getting, and the price of LPG, an alternative market based fuel.[7]

The second source of price variation is from bribes paid in addition to the subsidized unit price. Therefore, although equation 9 controls for the variables that may covary with both price and fuel collection time, there remains the problem of reverse causality: the household's decision on how much time to allocate to biomass fuel collection could influence its demand for kerosene, which may influence the additional amount the household must pay in bribes per liter of kerosene. To mitigate this simultaneity bias, I instrument for the subsidized price of kerosene in the current year with the subsidized price of kerosene in 2005, a lagged price measure.

While most papers address this type of simultaneity bias by simply replacing the endogenous variable with its lagged time value (Aschoff and Schmidt 2008; Bania, Gray and Stone 2007; Buch, Koch Koetter 2013), I follow Yogo (2004) and use the lagged value as an instrument. Reed (2015) shows, both theoretically and through simulations, that instrumenting rather than replacing the endogenous variable with its lagged value yields more consistent estimates, assuming the relevance and exclusion restrictions hold. The first stage F-tests and the significance of the first stage results reported in the next section confirms that relevance holds. The exclusion restriction is more difficult to prove, and is conditional on fully controlling for village level factors that may simultaneously affect both lagged kerosene price and the outcome variables of interest.

[7]The mean unit price of LPG in India is 30.4 INR per liter, with a standard deviation of 4.1 INR. The price distribution varies from state to state, ranging from an average of 25 INR per liter to 49 INR per liter with standard deviations of 1 INR to 15 INR respectively. The marginal effect of a one unit increase in LPG price increases monthly household consumption of kerosene by .023 liters, holding constant kerosene price and all the household and village level controls used in equation 9. This effect is small, but highly significant at the 1 percent level. Therefore, I include LPG price as a control in my specifications.

As an additional check on the validity of using a TSLS method over OLS, I conduct a Durbin-Wu-Hausman test, which tests whether kerosene price is endogenous by comparing the OLS estimate of the structural parameters in the IV regression to that of the TSLS. The chi-square p-values indicate that I can reject the null hypothesis that kerosene can be treated as exogenous. The test statistic is significant at the 5 percent level for girls and boys and at the 1 percent level for women and men. [8]

I estimate the IV model using two-stage least squares, where equation 9 is the second stage equation. The first stage equation is:

$$KerosenePrice_h^s = \beta_0 + \beta_1 LaggedKerosenePrice_h + \beta_2 Controls_h + \mu_h, \tag{10}$$

where $LaggedKerosenePrice_h$ is the instrument, and is matched exactly to the same household h that reported paying the current $KerosenePrice_h^s$. There were no unusual price hikes resulting from shortages of kerosene in 2005 that could have caused families to stock up on the commodity; therefore lagged price should be uncorrelated with unobserved current household-level shocks that may influence current demand for kerosene and by extension fuel collection time. Although it is unlikely that lagged price affects current outcomes of interest through current shocks, the exclusion restriction may be violated if the three village-level covariates outlined above are not enough to fully control for village-level factors that are persistent over time, and that may influence both lagged kerosene price as well as the outcomes of interest. If this is true, the TSLS estimates will be biased away from zero. The validity of the relevance assumption that $Cov(LaggedKerosenePrice, KerosenePrice) \neq 0$ is shown empirically through a first stage F-test for joint significance of all regressors in the next section.

[8] The p-values for girls, boys, women, and men for the Durbin-Wu-Hausman test statistic conducted for equation 9 are 0.0139, 0.0304, 0.000, and 0.000 respectively.

4.2.2 Effect of kerosene price on water collection time

After estimating the effect of kerosene price on children's fuel collection time, I answer question (2): Where does this extra time spent collecting fuel come from? Are children substituting away from time spent in school, or from other important household tasks such as collecting drinking water for the household?

The same endogeneity concerns stemming from state-induced price variation discussed above apply when estimating the effect on water collection time. Household wealth and village-level factors may covary with both water collection time and kerosene price. Therefore, I control for the same household wealth and village-level variables as in equation 9.

The simultaneity bias issue that stems from variation in bribe costs may also be a problem for this estimation, though likely to a lesser extent than for equation 9. I conduct another Durbin-Wu-Hausman test and reject the null that kerosene price is exogenous in equation 11 at the 5 percent level for girls, 10 percent level for boys and women, and 1 percent level for men.[9] Therefore, I follow the same two-stage least squares IV estimation strategy to estimate the impact of kerosene price on the minutes per week that children of gender s spend collecting water. The following is the second stage regression for households that report having their water source located outside of their home:

$$WaterCollectionTime_h^s = \beta_0 + \beta_1 KerosenePrice_h + \beta_2 Controls_h + \beta_3 WaterAvailability_h + \epsilon_h, \tag{11}$$

where $Controls_h$ is the same vector of controls used in equation 9, and $WaterAvailability_h$ is a binary variable that controls for whether the household reports water availability as generally "adequate". This is included in case the price of kerosene systematically varies with the quality of water infrastructure across households. I instrument for kerosene price with the same lagged price.

[9] The p-values for girls, boys, women, and men for the Durbin-Wu-Hausman test statistic conducted for equation 11 are 0.0357, 0.0786, 0.0875, and 0.000 respectively.

The first stage regression is:

$$KerosenePrice_h = \beta_0 + \beta_1 LaggedKerosenePrice_h + \beta_2 Controls_h + \beta_3 WaterAvailability_h + \mu_h \tag{12}$$

4.2.3 Effect of kerosene price on education time

The Durbin-Wu-Hausman test for equation 13, which estimates the effect of kerosene price on time spent in school does not give any significant test statistics for girls or boys.[10] Therefore, I fail to reject the null hypothesis that kerosene price is exogenous in this specification. This suggests that the simultaneity bias addressed using the IV for estimating the effects of price on fuel and water collection is likely not a concern in the case of education. This makes intuitive sense; after controlling for wealth measures and village-level factors, there is little reason to believe the number of hours a child spends in school will cause a change in kerosene price. Consequently, I estimate the impact of kerosene price on time children spend in school using OLS. [11] Again, I limit my analysis to households with a water source outside of the compound, in order to maintain the same sample as equation (4). The equation is given by:

$$SchoolHours^s_{ih} = \beta_0 + \beta_1 KerosenePrice_h + \beta_2 Controls_h + \beta_3 SchoolControls_{ih} + \epsilon_h. \tag{13}$$

Note that in this specification, the unit of analysis is the individual rather than the household. The dependent variable $SchoolHours^s_{ih}$ gives the number of hours per week individual i of sex s in household h spends in school. As usual β_1 is the variable of interest. $Controls_h$ is the same vector of controls as in equation 9. $SchoolControls_{ih}$ is an additional vector of school related controls that includes the distance from the household to the school, the student's caste, the student's grade level, age, the highest level of female education in the student's household, and whether the household reports the teacher being absent "sometimes", "often" or "rarely/never."

[10] The p-values for girls and boys for the Durbin-Wu-Hausman test statistic conducted for equation 13 are 0.5151 and 0.8497 respectively.

[11] Estimates from the TSLS version of this specification are very similar to OLS estimates, as reported in section 5.

4.3 Limitations to reducing endogeneity

A key limitation of this analysis is that it relies on cross-sectional variation in prices. The lack of panel data means that I cannot conduct a fixed effects analysis and control for unobserved time-invariant effects that could be confounding the estimates to help further mitigate the endogeneity of kerosene price.

It is also worth emphasizing again that the complexity and corruption of India's PDS pricing system causes prices to vary endogenously. I control for a wide range of relevant household wealth and village-level variables and use an IV strategy to mitigate the key sources of price variation outlined in section 4.2. However, a key threat to this identification strategy is that these control variables likely only rule out one of two ways that the exclusion restriction can be violated. The first way the exclusion restriction can be violated is if lagged kerosene price is correlated with current household level factors and shocks which affect current demand for kerosene (and therefore fuel collection time). I mitigate this problem by controlling for three household level wealth variables. Because the state-issued PDS kerosene prices are not determined by any household-level factors beyond wealth, these controls should be enough to rule out this particular way that the exclusion restriction can be violated.

The second way the exclusion restriction can be violated is if lagged kerosene price is correlated with unobserved, time persistent village-level factors that also affect the outcomes of interest. For example, the quality of the roads that give access to each village may vary systematically with the lagged kerosene price (possibly due to differences in transportation costs), and also influence the time spent collecting fuel or water (the isolation of a village may vary systematically with biomass fuel availability, or with distance to the water collection source), violating the exclusion restriction assumption. Although I control for road quality, among other village-level covariates, I cannot rule out the possibility that I am missing other important village-level factors that may vary with both the instrument and the outcome variables of interest. Therefore, my results may be biased away from zero. The true coefficients on kerosene price for girls' and boys' fuel and water collection times may be smaller in magnitude that those reported in the next section, making them an upper bound.

5 Results

Table 3 presents the first stage results of instrumenting for kerosene price with lagged kerosene price from 2005 as the excluded instrument and the vector of control variables outlined in equations 10 and 12 as the included instruments. Lagged kerosene price is significantly correlated with current kerosene price for all regressions. I use the reported Wald F-statistic based on the Kleibergen–Paap rk statistic to conduct a weak instrument test for each model. In the case of non-i.i.d. standard errors, as is the case in my analysis, Baum, Schaffer, and Stillman (2007) recommend using Staiger and Stock's (1997) "rule of thumb" for weak instruments, where a first stage F-statistic > 10 implies that the instrument is not weak. The F-statistic reported for all first stage regressions meets this rule, except for the sample of girls in column 1, where the F-statistic=9.5, which indicates that the instrument just barely misses the threshold and should be interpreted with caution. The F-statistic for boys in column 1 is considerably less than 10, so we cannot make any definite conclusions about boys' fuel collection time.

Table 3: First stage point estimates of current kerosene price on lagged kerosene price

	(1) Fuel collection (min/week)	(2) Water collection (min/week)
Sample		
Girls	0.457***	0.458***
	(0.148)	(0.0604)
N	382	4055
F-statistic	9.5	47.6
Boys	0.319***	0.438***
	(0.147)	(0.0635)
N	330	3801
F-statistic	4.7	47.6
Women	0.592***	0.425***
	(0.0766)	(12.32)
N	2526	7843
F-statistic	59.8	100.3
Men	0.597***	0.461***
	(0.0804)	(0.0494)
N	1727	5758
F-statistic	55.1	87.1

$p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parenthesis and clustered at the district level. The excluded instrument is lagged kerosene price. Included instruments not shown for regressions under column 1 are annual income, annual per capita expenditure, above or below the poverty line, quality of village roads, distance to a paved road, urban/rural, number of household members of sex s under/over age 15 in the household (depending on the sample), total number of family members, distance to the nearest ration shop, the number of hours of electricity per day that the household reports getting, and the price of LPG. Included instruments for regressions under column 2 include those used in column 1 plus water availability.

Table 4 presents the second stage results using the fitted kerosene price values for the fuel and water collection equations, and the OLS results for the education equations. Each coefficient is the effect of a one INR increase in kerosene price on three outcome variables: fuel collection, water collection, and schooling. Regressions are run for four different subsamples: girls, boys, women, and men. Column 1 shows that a 1 INR increase in kerosene price increases both girls' and boys' fuel collection time. The coefficients are significant at the 5 and 10 percent levels respectively, but the overlapping confidence intervals indicate that they are not statistically significantly different from each other.

The negative coefficients for girls and boys under column 2 show that some of this fuel collection time is substituted away from water collection for children, and that parents compensate for this decrease in water collection time.[12] Surprisingly, men compensate by a statistically significantly larger amount of time than women. Also surprising is column 3, which shows that no time is substituted away from time spent in school for both boys and girls.[13] This is unexpected, given that the literature shows a clear home production and human capital time trade off for children, particularly girls. One possible explanation for this result is that human capital acquisition and home production trade-offs may only become apparent after age 15 in India, when girls near a marriageable age and the household's perceived value of her human capital θ_g drops considerably. It is also important to note that because the decrease in time children spend collecting water (column 2) is not as large as the increase in their fuel collection times (column 1), a bulk of the time must also be coming out of a fourth omitted category outside of fuel, water, and education. This includes other household production tasks, leisure, or child labor performed by children, none of which are measured explicitly in my analysis. A decrease in time allocation in any of these

[12] A possible question we can ask from these results is whether we see children becoming more efficient at collecting water as a result of the kerosene price increase. If column 2 of table 4 did not show a significant increase in parents' water collection time, it may be possible that children became more efficient in collecting water, because the decrease in the time spent collecting water is not as large as the increase in the time spent collecting fuel, indicating that the same amount of water was collected (the household would have no reason to suddenly require less drinking water), but at a faster rate. However we do see an increase in the water collection time of parents which compensates for the decrease in children's water collection time. This suggests that there may not be any change in children's water collection efficiency. and that parents make up for the reduced water collection time.

[13] I ran the same analysis after including time spent studying and time spent in extra tutoring and the same insignificant results hold. In addition, a TSLS model of the effect of kerosene price on schooling also gives insignificant results.

categories, particularly leisure and child labor, would have important child welfare implications.

Given that the average difference between the reported subsidized kerosene price and the market price is about 6 INR in the IHDS data, the effect of the kerosene subsidy program on girls' and boys' time allocation can be quantified by multiplying the coefficients for girls and boys in column 1 by 6 INR. This calculation suggests that the kerosene subsidy gives girls and boys in the average household an extra 14.9 hours per week and 13.1 hours per week respectively for the household to reallocate as it wishes. That the results indicate that none of these hours are reallocated to extra school time for children is consistent with the fact that the average girl and boy in the data each spend about 32 hours per week, or 6.4 hours per school day, in school, which is reasonably close to the maximum amount of time a child can be in school per day.

Table 4: TSLS point estimates of kerosene price on fuel collection and water collection, and OLS estimate of kerosene price on school time

	(1) Fuel collection (min/week)	(2) Water collection (min/week)	(3) Schooling (hours/week)
Sample			
Girls	148.78**	-17.16**	0.10
	(75.72)	(8.61)	(0.26)
N	382	4055	1205
Boys	131.09*	-15.07*	-0.11
	(78.02)	(8.49)	(.30)
N	330	3801	1262
Women	7.48	23.77*	
	(19.09)	(12.30)	
N	2526	7843	
Men	26.52	63.98***	
	(19.57)	(11.25)	
N	1727	5758	

$p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parenthesis and clustered at the district level. Control variables not shown for regressions under column 1 are annual income, annual per capita expenditure, above or below the poverty line, quality of village roads, distance to a paved road, urban/rural, number of household members of sex s under/over age 15 in the household (depending on the sample), total number of family members, distance to the nearest ration shop, the number of hours of electricity per day that the household reports getting, and the price of LPG. Control variables for regressions under column 2 include those used in column 1 plus water availability. Control variables for regressions under column 3 include those used in column 1 plus distance to school, caste, grade level, age, highest level of female education in household, and teacher absence.

5.1 Rethinking the theory behind time allocation decisions and gender bias

These empirical results have several implications for the theoretical model presented in equation 1. Columns 2 and 3 of table 4 imply that $\frac{\partial T^b_{educ}}{\partial p_m} = 0$ and $\frac{\partial T^b_{water}}{\partial p_m} < 0$ for boys. This is consistent with the model's prediction. An increase in fuel collection time causes boys to substitute time away from another household production task, rather than away from their education time, which is valued highly by the household ($\theta_g < \theta_b$). However, the results for girls call the assumptions made in the model about how households value sons and daughters into question.

Columns 2 and 3 imply that $\frac{\partial T^g_{educ}}{\partial p_m} = 0$ and $\frac{\partial T^g_{water}}{\partial p_m} < 0$ for girls. The model predicts that these marginal effects can only be simultaneously true for girls with zero time allocated to education, $T^g_{educ} = 0$. Girls with no education time cannot decrease their education time farther, and must therefore decrease their water collection time in order to compensate for their increased fuel collection time. However, I find that it is unlikely that the average girl in India spends zero time in school, particularly given that the summary statistics in table 2 shows that girls' average school time is greater than zero. This implies that the conditions I impose on the parameters that define the value the household places on different activities for girls versus for boys, $\alpha_g > \alpha_b$ and $\theta_g < \theta_b$, are not assumptions that hold in the data. The empirical results suggest that households do not value girls' and boys' household production labor or their human capital differently.

This conclusion is inconsistent with the large body of literature showing that households in India will often behave with gender bias. The empirical results of this paper suggest that the assumptions imposed in the theoretical model may not hold generally, and may be conditional on other factors, such as children's age (households may start to show biased behavior for girls older than age 15 as she nears a marriageable age). More empirical studies are required to corroborate the results of this paper, and to refine the way we conceptualize the way households make trade-offs between human capital acquisition for its children and home production activities.

6 Conclusion

6.1 Policy implication

The relationship between household energy use and gender and the importance of reducing the time constraints that come with physically demanding tasks such as gathering biomass fuel has been emphasized by development organizations as a possible way to increase the welfare of girls and women. The United Nations Development Programme (2011) states that, "energy poverty leads to drudgery, greater health risks and a lack of time to focus on income-generating, educational or other self nurturing (e.g. leisure) activities." India's TPDS system was created on the principle that subsidies are an important tool for poverty reduction, and that fuel subsidies in particular may act as a way to not only loosen a household's budget constraint but also to free up girls' time so they can invest it in human capital acquisition activities. However, my paper suggests that a change in kerosene subsidy may not affect girls' education.

This is an encouraging finding from a welfare perspective. Although it is a cleaner alternative to burning hazardous biomass fuels, kerosene has its own set of well documented hazards, from the risk of fires and explosions to the health problems that result from exposure to kerosene's combustion products (Lam et al., 2012). The results of this paper suggest that governments may be able to reduce kerosene subsidies without impacting education as they search for cheaper and cleaner alternatives to subsidize, such as solar lighting (Sharma, 2017).

The results from this paper can give some insight into the household time allocation outcomes that the Indian government can expect from a recent policy that aims to reduce the kerosene subsidy. Since August 2016, the Indian government has ordered state oil companies to keep raising prices of subsidized kerosene by 25 paise (.25 INR) every two weeks until the subsidy is eliminated (Choudhary, 2017). Consequently, the subsidized kerosene price has been steadily increasing to meet the market price. This paper suggests that the average household may be able to mitigate potentially adverse effects on children's school time in response to this policy.

6.2 Future research

Future research with better time data and fewer endogeneity concerns may help to verify the claims of this paper, which must be interpreted with caution. The lack of an effect of kerosene price on education time should not be interpreted as a lack of any welfare decreasing effect. The unobserved category beyond fuel collection, water collection, and education time includes categories like leisure, which could be affected by kerosene price and therefore have important welfare implications for children. Therefore, future research using more complete data on these omitted categories may help complete the time reallocation story for Indian households. Other welfare decreasing effects of the kerosene price may be exposed if we look at children's time allocation across fuel collection time, all other household production tasks (including water collection), education, leisure, and child labor time separately.

In addition, given the ever important policy goal of increasing women's economic empowerment in India, other marginal effects of interest are the effects of a kerosene price change on the time adult women spend working on their own businesses, on a family enterprise, or in market work outside of the household. This requires conducting the study using a more complete and detailed dataset with variables on how each household member allocates his/her time across these specific categories.

References

Angrist, Joshua D., and Jörn-Steffen Pischke. 2009. Mostly harmless econometrics: An empiricist's companion. Princeton, New Jersey: Princeton University Press.

Aschhoff, B., and T. Schmidt. 2008. "Empirical evidence on the success of R and D cooperation—Happy together?" *Review of Industrial Organization* 33:41–62.

Bania, N., Gray, J.A., and J.A. Stone. 2007. "Growth, taxes, and government expenditures:

Growth hills for U.S. states." *National Tax Journal LX* 193-204.

Barcellos, Silvia Helena, Leandro S. Carvalho, and Adriana Lleras-Muney. 2014. "Child Gender and Parental Investments In India: Are Boys And Girls Treated Differently?" *American Economic Journal: Applied Economics* 6(1): 157–189.

Baum, Christopher, Schaffer, Mark and Stillman, Steven. 2007. "Enhanced routines for instrumental variables/generalized method of moments estimation and testing." *Stata Journal*, 7(4): 465-506.

Becker, Gary. 1965. "A Theory of the Allocation of Time." *The Economic Journal*, 75(299): 493-517.

Bhalotra, Sonia R. and Tom Cochrane. 2013. "Where Have All the Young Girls Gone? Identification of Sex Selection in India." IZA Discussion Paper No. 5381.

Bjorkman-Nyqvist, Martina. 2013. "Income shocks and gender gaps in education: Evidence from Uganda." *Journal of Development Economics* 105: 237-253.

Buch, C., Koch, C.T., and M. Koetter. 2013. "Do banks benefit from internationalization? Revisiting the market power–risk nexus." *Review of Finance* 17:1401–1435.

Chakrabarti, Suman, Avinash Kishore, and Devesh Roy. 2016. "Arbitrage and Corruption in Food Subsidy Programs: Evidence from India's Public Distribution System." *2016 Agricultural and Applied Economics Association Annual Meeting.*

Choudhary, Sanjeev. Aug. 3, 2017. "After diesel and LPG, government to now end subsidy on kerosene." *Economic Times.* Retrieved August 30, 2017 from http://economictimes.indiatimes.com/industry/energy/oil-gas/after-diesel-and-lpg-government-to-now-end-subsidy-on-kerosene/articleshow/59888617.cms.

Clarke, Kieran. 2014. "Kerosene Subsidies in India" *International Institute for Sustainable Devel-*

opment. Retrieved on August 29, 2017.

CMS Transparency India. "Corruption Study 2012: Expanding Slums, Growing Corruption." 2012. *CMS.* Retrieved January 31, 2018 from http://cmsindia.org/publications/India-Corruption-study-2012.pdf

Desai, Sonalde, and Vanneman, Reeve. India Human Development Survey-II (IHDS-II), 2011-12. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2018-08-08. https://doi.org/10.3886/ICPSR36151.v6

Drèze, Jean, and Geeta Gandhi Kingdon. 2001. "School Participation in Rural India." *Review of Development Economics* 5(1): 1–24

Edmonds, Eric V. and Norbert Schady. 2012. "Poverty Alleviation and Child Labor." *American Economic Journal: Economic Policy, American Economic Association.* 4(4): 100-124

Edmonds, Eric V., Petia Topalova, and Nina Pavcnik. 2009. "Child Labor and Schooling in a Globalizing World: Some Evidence from Urban India." *Journal of the European Economic Association.* 7(2/3): 498-507

Eswaran, Mukesh, Bharat Ramaswami, and Wilima Wadhwa. 2013. "Status, Caste, and the Time Allocation of Women in Rural India." *Economic Development and Cultural Change* 61(2): 311-333.

Fafchamps, Marchel and Jackline Wahba. 2006. "Child Labor, Urban Proximity and Household Composition." *IZA Discussion Paper No. 1966.*

Gimenez-Nadal, Jose Ignacio, and Almudena Sevilla. 2012. "Trends in time allocation: A cross-country analysis." *European Economic Review* 56(6): 1338-1359.

GK Today. July 28, 2017. "Targeted Public Distribution System." *General Knowledge Today* Retrieved January 31, 2018 from https://www.gktoday.in/gk/targeted-public-distribution-system/.

Gronau, Reuben. 1977. "Leisure, Home Production, and Work–the Theory of the Allocation of Time Revisited." *Journal of Political Economy*, 85(6): 1099-1123.

Gupta, Monica Das. 1987. "Selective Discrimination against Female Children in Rural Punjab, India." *Population and Development Review* 13(1): 77-100.

Khan, Farida Chowdhury. 2012. "Household Work, Labor Time, and the Schooling of Girls in Rural South Asia." *The Journal of Developing Areas.* 46(2): 249-267

Lam, Nicholas L., Kirk R. Smith, Alison Gauthier, and Michael N. Bates. 2012. "Kerosene: A Review of Household Uses and Their Hazards in Low and Middle Income Countries." *Journal of Toxicology and Environmental Health.* Part B, Critical Reviews, 15(6): 396–432

Manacorda, Marco and Furio C. Rosati. 2007. "Local Labor Demand and Child Labor." Understanding Children's Work Programme Working Paper. Available at SSRN: https://ssrn.com/abstract=1780255.

National Council of Applied Economics Research (NCAER). 2015. "Evaluation Study of Targeted Public Distribution System in Selected States." *Ministry of Consumer Affairs, Food and Public Distribution, Government of India.*

Pitt, Mark and, Mark Rosenzweig. 1990. "Estimating the Intrahousehold Incidence of Illness: Child Health and Gender-Inequality in the Allocation of Time." *International Economic Review*, 31(4): 969-80.

Redman, Barbara J. 1980. "The Impact of Women's Time Allocation on Expenditure for Meals Away from Home and Prepared Foods." *American Journal of Agricultural Economics* 62(2): 234-37.

Reed, William. 2015. "On the Practice of Lagging Variables to Avoid Simultaneity." *Oxford*

Bulletin on Economics and Statistics 77(6): 897–905.

Rosenblum, Daniel. 2017. "Estimating the Private Economic Benefits of Sons Versus Daughters in India." *Feminist Economics.* 23(1): 77-107

Rosenzweig, Mark R. and T. Paul Schultz. 1982. "Market Opportunities, Genetic Endowments, and Intrafamily Resource Distribution: Child Survival in Rural India." American Economic Review 72(4): 803–15.

Schady, Norbert R. 2004. "Do Macroeconomic Crises Always Slow Human Capital Accumulation?" *World Bank Economic Review.* 18(2): 131-154

Sharma, Shruti. Oct. 16, 2017. "As the Centre Weans India Off Kerosene Subsidies, How Should States Respond?" *The Wire.* Retrieved January 31, 2017 from https://thewire.in/187260/as-the-centre-weans-india-off-kerosene-subsidies-how-should-states-respond/.

Sharp, David C., David H. Ciscel, and Julia A. Heath. 1998. "Back To Becker: Valuing Women's Economic Contribution From Housework With Household Production Functions." *Journal of Forensic Economics* 11(3): 215-35.

Shepherd, Mary Elizabeth. 2008. Sex-Selective Abortion in India: The Impact on Child Mortality. Youngstown, NY: Cambria Press.

Skoufias, Emmanuel. 1993. "Labor Market Opportunities and Intrafamily Time Allocation in Rural Households in South Asia." *Journal of Development Economics.* 40: 277-310.

Staiger, Douglas, and James H. Stock. 1997. "Instrumental variables regression with weak instruments." *Econometrica* 65(3): 557–86.

World Health Organization. 2016. "Burning Opportunity: Clean Household Energy for Health, Sustainable Development, and Wellbeing of Women and Children." http://www.who.int/indoorair/publications/burning-opportunities/en/.

Yogo, M. 2004. Estimating the Elasticity of Intertemporal Substitution When Instruments Are Weak. *The Review of Economics and Statistics.* 86(3): 797-810.

Appendices

A A more complex household utility model

The household has preferences over a compost market good x and four household production functions: boy's human capital production Z_1; girl's human capital production Z_2; fuel production Z_3, which takes time spent collecting biomass fuel and purchased market based fuel m as inputs; and water production Z_4, which takes time spent collecting water as inputs.

$$\max_{x,\vec{T}} \quad U\big(x,\ \theta_g Z_1(T^g_{educ}),\ \theta_b Z_2(T^b_{educ}),\ Z_3(T^g_{fuel}, T^b_{fuel}, T^p_{fuel}, m),\ Z_4(T^g_{water}, T^b_{water}, T^p_{water})\big)$$

Subject to:

$T^g_{total} = T^g_{educ} + T^g_{fuel} + T^g_{water}$ *Total time girl has*

$T^b_{total} = T^b_{educ} + T^b_{fuel} + T^b_{water}$ *Total time boy has*

$T^p_{total} = T^p_{mkt} + T^p_{fuel} + T^p_{water}$ *Total time parents have*

$\omega = \gamma_g * T^g_{water} + \gamma_b * T^b_{water} + \gamma_p * T^p_{water}$ *Total amount of water needed for survival (exogenous)*

$e = m + \alpha_g * T^g_{fuel} + \alpha_b * T^b_{fuel} + \alpha_p * T^p_{fuel}$ *Total amount of fuel*

$e \geq \bar{e}$ *Total fuel must meet $\bar{e}$, the minimum amount of fuel needed for survival (exogenous)*

$p_x x + p_m m = w T^p_{mkt}$ *Budget constraint*

Similar to the main model in the paper, α_g, α_b, γ_g, γ_b can be viewed as the household's perceived fuel and water collection rates for girls and boys - the household's perception of which child's household labor is more considered more valuable. I assume $\alpha_g > \alpha_b$ and $\gamma_g > \gamma_b$. Similarly, θ_g and θ_b can be viewed as the value the household places on girls' and boys' human capital acquisition activities, which is influenced by the expected private returns from sons relative to daughters. I assume $\theta_g < \theta_b$.

B First order conditions and comparative statics derivation

The household faces the following optimization problem:

$$\max_{x,e,T^g_{educ}T^b_{educ}} \quad G(x,e) + \ \theta_g * Z_1(T^g_{educ}) + \ \theta_b * Z_2(T^b_{educ})$$

Subject to:

$T^g_{total} = T^g_{educ} + T^g_{fuel}$ *Total time girl has*

$T^b_{total} = T^b_{educ} + T^b_{fuel}$ *Total time boy has*

$e = m + \alpha_g * T^g_{fuel} + \alpha_b * T^b_{fuel}$ *Total amount of fuel*

$e \geq \bar{e}$ *Total fuel must meet $\bar{e}$, the minimum amount of fuel needed for survival*

$p_x x + p_m m = I$ *Budget constraint, where I is parents' income (exogenous)*

I assume that $x, e, T^g_{educ}, T^b_{educ}, T^g_{fuel}$, and T^b_{fuel} are strictly positive. The two time constraints and the budget constraint can be substituted into the expression for e to obtain the following two constraints:

$e = \frac{I + p_x x}{p_m} + \alpha_g(T^g_{total} - T^g_{educ}) + \alpha_b(T^b_{total} - T^b_{educ})$

$e \geq \bar{e}$

I use the method of Lagrange multipliers to derive the following first order conditions:

$$\mathcal{L} = G(x,e) + \ \theta_g * Z_1(T^g_{educ}) + \ \theta_b * Z_2(T^b_{educ}) + \lambda_1(e - m + \alpha_g * T^g_{fuel} + \alpha_b * T^b_{fuel}) + \lambda_2(e - \bar{e})$$

$$\frac{\partial \mathcal{L}}{\partial x} = \frac{\partial G}{\partial x} + \frac{\lambda_1 p_x}{p_m} = 0 \tag{B.1}$$

$$\frac{\partial \mathcal{L}}{\partial e} = \frac{\partial G}{\partial e} + \lambda_1 + \lambda_2 = 0 \tag{B.2}$$

$$\frac{\partial \mathcal{L}}{\partial T^g_{educ}} = \theta_g \frac{\partial Z_1}{\partial T^g_{educ}} + \lambda_1 \alpha_g = 0 \tag{B.3}$$

$$\frac{\partial \mathcal{L}}{\partial T^b_{educ}} = \theta_b \frac{\partial Z_1}{\partial T^b_{educ}} + \lambda_1 \alpha_b = 0 \tag{B.4}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_1} = e - \frac{I + p_x x}{p_m} - \alpha_g(T^g_{total} - T^g_{educ}) - \alpha_b(T^b_{total} - T^b_{educ}) = 0 \tag{B.5}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_2} = e - \bar{e} \geq 0, \quad \lambda_2 \geq 0; \quad \text{Complimentary slackness condition: } (e - \bar{e})\lambda_2 = 0 \tag{B.6}$$

Whether or not B.6. is a binding condition depends on the sign of λ_2. First order condition B.2. can be manipulated to express λ_2 as:

$$\lambda_2 = -\frac{\partial G}{\partial e} - \lambda_1,$$

where λ_1 can be derived from first order condition B.3. as:

$$\lambda_1 = -\frac{\theta_g}{\alpha_g} \frac{\partial Z_1}{\partial T^g_{educ}}.$$

$\lambda_2 > 0$ as long as λ_1, the marginal benefit of education scaled by the perceived benefit, is greater in magnitude than $\frac{\partial G}{\partial e}$, the marginal benefit of an additional unit of fuel. I assume that this condition holds. Therefore, $\lambda_2 > 0 \implies e - \bar{e} = 0$. $\bar{e}$ can then be substituted for e in the objective function and constraints, which simplifies the household's optimization problem to:

$$\max_{x, T^g_{educ} T^b_{educ}} \quad G(x, \bar{e}) + \ \theta_g * Z_1(T^g_{educ}) + \ \theta_b * Z_2(T^b_{educ})$$

Subject to:

$\bar{e} = \frac{I + p_x x}{p_m} + \alpha_g(T^g_{total} - T^g_{educ}) + \alpha_b(T^b_{total} - T^b_{educ})$[14]

[14] I impose assumptions that allow me to eliminate the $e \geq \bar{e}$ constraint in order to allow m to be implicitly chosen once the consumer picks T^g_{educ} and T^b_{educ}, rather than making m an endogenous variable that the household must explicitly pick. This was in order to minimize the number of endogenous variables in the theoretical model in order to simplify comparative statics computation. By allowing $e = \bar{e}$, the endogenous variables in the equation $\bar{e} = m + \alpha_g * T^g_{fuel} + \alpha_b * T^b_{fuel}$ are T^b_{fuel} and T^g_{fuel}. The value of $\bar{e}$ is exogenously given, so m is chosen implicitly.

The method of Lagrange multipliers gives the following first order conditions:

$$\frac{\partial \mathcal{L}}{\partial x} = \frac{\partial G}{\partial x} + \frac{\lambda p_x}{p_m} = 0 \tag{B.7}$$

$$\frac{\partial \mathcal{L}}{\partial T^g_{educ}} = \theta_g \frac{\partial Z_1}{\partial T^g_{educ}} + \lambda \alpha_g = 0 \tag{B.8}$$

$$\frac{\partial \mathcal{L}}{\partial T^b_{educ}} = \theta_b \frac{\partial Z_2}{\partial T^b_{educ}} + \lambda \alpha_b = 0 \tag{B.9}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \bar{e} - \frac{I + p_x x}{p_m} - \alpha_g(T^g_{total} - T^g_{educ}) - \alpha_b(T^b_{total} - T^b_{educ}) = 0 \tag{B.10}$$

I use the implicit functions approach to comparative statics and apply Cramer's rule to derive the following expression for $\frac{\partial T^g_{educ}}{\partial p_m}$:

$$A = \begin{vmatrix} \frac{\partial^2 G}{\partial x^2} & 0 & 0 & \frac{p_x}{p_m} \\ 0 & \theta_g \frac{\partial^2 Z_1}{\partial (T^g_{educ})^2} & 0 & \alpha_g \\ 0 & 0 & \theta_b \frac{\partial^2 Z_2}{\partial (T^b_{educ})^2} & \alpha_b \\ \frac{p_x}{p_m} & \alpha_g & \alpha_b & 0 \end{vmatrix}$$

$$B = \begin{vmatrix} \frac{\partial^2 G}{\partial x^2} & \frac{\lambda p_x}{p_m^2} & 0 & \frac{p_x}{p_m} \\ 0 & 0 & 0 & \alpha_g \\ 0 & 0 & \theta_b \frac{\partial^2 Z_2}{\partial (T^b_{educ})^2} & \alpha_b \\ \frac{p_x}{p_m} & \frac{p_x x}{p_m^2} - \frac{I}{p_m^2} & \alpha_b & 0 \end{vmatrix}$$

$$\frac{\partial T^g_{educ}}{\partial p_m} = \frac{B}{A} \tag{B.11}$$

$$= \frac{\alpha_g \theta_b \frac{\partial^2 Z_2}{\partial (T^b_{educ})^2} \left(\lambda \frac{p_x^2}{p_m^3} - \frac{\partial^2 G}{\partial x^2} \right)}{\frac{\partial^2 G}{\partial x^2} \left(-\theta_g \alpha_b^2 \frac{\partial^2 Z_1}{\partial (T^g_{educ})^2} - \alpha_g^2 \theta_b \frac{\partial^2 Z_2}{\partial (T^b_{educ})^2} \right) - \frac{p_x^2}{p_m^2} \theta_b \theta_g \frac{\partial Z_1^2}{\partial (T^g_{educ})^2} * \frac{\partial Z_2^2}{\partial (T^b_{educ})^2}} \tag{B.12}$$