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Female Labor Force Participation and Household Dependence on Biomass Energy: Evidence from National Longitudinal Data

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Summary. — Air pollution from household biomass combustion is an important cause of poor health in developing countries. This study employs national-level longitudinal data for up to 175 countries during 1990–2010 and finds that female labor force participation is associated with reductions in household biomass energy use. Consistent with the "fuel stacking" model, higher incomes are linked to use of other types of energy by households, but not significantly associated with reductions in use of biomass energy. The results highlight the multifaceted nature of household energy transitions and suggest an avenue by which female empowerment can lead to improved health outcomes.

Key words — biomass fuel, solid fuel, household, energy, gender, fuel stacking

"*It is the availability or otherwise of women's unpaid labor time that is the crucial factor in determining the extent of wood fuel use.*"
[Nathan and Kelkar (1997, pp. 211–212)]

1. INTRODUCTION

Around 2.8 billion people, or 41% of the world's population, rely on traditional fuels – mostly biomass, but also coal – for the majority of the energy they use for cooking (Bonjour *et al.*, 2013). Reliance on biomass – non-fossil plant or animal material, including wood, charcoal, dung, and crop residues – for residential energy needs is highest in the poorest countries, particularly rural areas. In the Democratic Republic of the Congo (DRC), for instance, biomass provides around 98% of the primary energy consumed by households for uses other than transport (which includes cooking, heating, and lighting). The average person in the DRC uses about eight times as much household-level biomass energy as the average person in the United States (US) (International Energy Agency [IEA], 2012).

Unventilated use of solid fuels at the household level is a leading cause of respiratory and other health problems, with estimates for 2012 indicating that around 4.3 million deaths per year are attributable to household air pollution from the combustion of biomass and coal (World Health Organization [WHO], 2014a).[1] Despite ongoing growth in the size of the global population, this has fallen from an estimated 4.6 million in 1990 (Lim *et al.*, 2012), in part due to substitution toward more modern energy sources such as kerosene, liquefied petroleum gas (LPG), natural gas, and electricity. Household air pollution is nevertheless believed to kill more people than outdoor particulates pollution; unimproved water and sanitation; or child and maternal undernutrition (Lim *et al.*, 2012). Household air pollution is cited as the leading health risk factor in South Asia, a region of 1.6 billion people, and the second-ranked health risk in much of sub-Saharan Africa (Lim *et al.*, 2012). In low-income countries, air quality in the home can often be even hundreds of times worse than the safe limits identified for outdoor areas (WHO, 2006). Women and children typically face the greatest exposure (Edwards & Langpap, 2012). Epidemiological studies have linked household air pollution to conditions such as stroke, ischemic heart disease, chronic obstructive pulmonary disease, respiratory infections, lung cancer, and tuberculosis (Mishra, Retherford, & Smith, 1999; Perez-Padilla, Schilmann, & Riojas-Rodriguez, 2010; WHO, 2014a).

Because the use of advanced low-emission biomass cook stoves in developing countries is rare, residential combustion of biomass energy is closely correlated with human exposure to household biomass-related pollution in these countries (Bonjour *et al.*, 2013). There have consequently been numerous policy initiatives to encourage shifts toward modern fuels (Maes & Verbist, 2012). The international community is currently seeking universal access to modern energy under the "Sustainable Energy for All" initiative (United Nations, 2014; World Bank, 2013).

There are a number of additional challenges faced by households dependent on biomass energy. In rural areas many people allocate considerable time to the collection of wood and other bio materials, displacing schooling and other productive activities (Cecelski, 1987). The collectors, often women and children, are exposed to safety risks while walking to gather household biomass materials, and can be left exhausted from carrying heavy loads International Institute for Applied Systems Analysis [IIASA], 2012; Wamukonya, 2004; Warwick & Doig, 2004). Because of its consequences for health and household productivity, biomass energy dependence is cited as a key contributor to families being trapped in poverty (Duflo, Greenstone, & Hanna, 2008) and is among the indicators used in efforts to measure multidimensional poverty (Alkire, Roche, & Seth, 2013).

In addition to these household-level effects, residential biomass energy use involves negative externalities outside the home. Emissions from biomass combustion contribute to outdoor pollution at the local (e.g., particulates) and global (e.g., methane, black carbon) scales (IEA, 2006; Martin, Glass, Balbus, & Collins, 2011).[2] The collection of biomass for household energy can in some instances contribute to forest loss and degradation (Arnold, Köhlin, & Persson, 2006),

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although demands for agricultural land and for timber for industrial purposes are more important drivers of global deforestation (Arnold & Persson, 2003; Bailis, 2004; Crewe, 1997; Dewees, 1989). Competition over biomass resources is the source of some community conflicts (Mark & Timothy, 2009). At the same time, many people in both rural and urban areas of developing countries share in commercial, employment, and other benefits from biomass collection and use (see Schure, Levang, & Wiersum, 2014, for a recent study of the DRC).

Research on the determinants of household energy use has often focused on the role of household incomes, with numerous studies examining the idea that higher incomes see households substitute to better-quality energy types as they climb an "energy ladder" (Barnes & Floor, 1996; Hosier, 2004; Leach, 1992). More recently the household energy transition has typically been framed as one of "fuel stacking": as incomes increase from low levels, households add more modern energy sources such as kerosene, LPG, natural gas, and electricity to their energy bundles, but do not necessarily phase out biomass energy use altogether (Masera, Saatkamp, & Kammen, 2000; van der Kroon, Brouwer, & van Beukering, 2013). Even many well-off households continue to use some biomass energy for activities such as traditional cooking and winter log fires.

Income may not be the whole story, however. Because women are often the principal collectors and users of biomass in rural areas of many developing countries, women's participation in paid employment might play a role in transitions away from household biomass energy.[3] Specifically, a higher opportunity cost of females' time as females enter the labor force increases the relative cost of biomass collection and use, and so might encourage transitions to other (less time-intensive) energy sources.[4] In addition to this *supply-side* channel, increased female participation in the labor force is likely to also reduce the *demand* for residential energy use (including biomass energy) as fewer people are at home through the day (and/or night).[5] While some micro-level evidence has been tabled on the ability for improved economic opportunities for women to reduce residential biomass energy dependence (e.g., Israel, 2002), there has yet to be a macro, aggregate-level investigation of the issue. This study does so, empirically testing the hypothesis of Nathan & Kelkar cited in our leading quote.

Our approach is to employ national longitudinal data on household biomass combustion for an international sample for the period 1990–2010. We utilize biomass energy data from four sources: the International Energy Agency (IEA, 2012), Bonjour *et al.* (2013), the United Nations (UN, 2013), and the Food and Agricultural Organization (FAO, 2014). Each takes a different approach to definitions and measurement, as will be discussed. We are careful to note that the nature of residential biomass use means that each measure is at best a rough proxy and that our results, while interesting, need to be read in this light. We use a variety of estimation approaches, including fixed-effects estimations and the difference and system generalized method of moments (GMM) estimators of Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). To our knowledge, this is the first study to use national longitudinal data to investigate the determinants of residential biomass energy use; prior studies typically rely on micro-level data for households from a single country at a point in time (e.g., Lee, 2013; Pandey & Chaubal, 2011; Song, Aguilar, Shifley, & Goerndt, 2012). We also explore the factors associated with the use of *other* (non-biomass) energy by households.

The paper is organized as follows. Section 2 reviews existing evidence on household energy transitions. Section 3 details our approach for examining the factors associated with household biomass energy use and discusses the data. Section 4 presents the main results. Section 5 concludes.

2. INITIAL EVIDENCE

Table 1 presents IEA (2012) data on per capita household primary energy consumption by energy source for the low-, middle-, and high-income country groups, and also for six example countries. The data indicate that people in low-income countries on average consume close to 200 kilograms (oil equivalent) of biomass energy at the household level each year. Biomass accounts for more than 90% of primary household energy consumption (excluding transport) in these countries. People in countries with higher incomes typically use less biomass energy for household purposes, and much more natural gas and electricity. Biomass provides a small share of the household energy consumed in Japan and the US, for example.

Globally, total biomass energy use has increased only marginally since the Industrial Revolution, despite a substantial increase in the global population and in use of other energy types (IIASA, 2012). As a result, the share of biomass in total primary energy use has been declining

Table 1. *Household per capita primary energy use, by energy source, 2010*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average per capita household-level primary energy (kgoe) from…						Total
	Biomass	Coal, oil products	LPG	Natural gas	Electricity	Other	
Low-income countries	193.3	3.1	0.5	3.3	5.1	0.0	205.3
Middle-income countries	122.6	20.4	16.8	31.5	30.1	17.8	239.2
High-income countries	43.1	72.5	21.7	241.2	249.0	25.4	653.0
Example countries							
D.R. of Congo	270.2	1.4	0.0	0.0	2.9	0.0	274.6
India	110.5	10.2	11.3	0.0	10.9	0.0	142.9
China	149.2	43.1	13.1	14.2	32.9	13.5	266.0
Brazil	39.9	0.0	32.2	1.2	47.8	0.0	121.1
Japan	0.2	69.5	39.0	71.9	206.0	3.3	389.9
United States	32.5	46.3	23.0	359.0	401.9	4.6	867.3

Notes: World Bank income classifications as of July 2012 are used. The country group averages were calculated using data for a total of 135 countries. Biomass includes charcoal. LPG is separated from other oil products. kgoe = kilograms oil equivalent. Source: IEA (2012).