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Access to Modern Energy: a Review of Impact Evaluations

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Summary

Universal access to modern energy services, in terms of access to electricity and to modern cooking facilities, has been recognized a fundamental challenge for development and is likely to be included in the post-2015 Sustainable Development Goals. Despite a strong praise for action and several programs at both national and international level, very few impact evaluation studies try to shed light on the causal relationship between access to energy and development, by also allowing decision makers to rigorously assess cost-effectiveness and efficiency of policies and programs. This work attempts to review the literature on existing impact evaluation of access to electricity and modern cooking facilities. For access to electricity we consider as outcomes labour markets, time allocation, household welfare (consumption, income, schooling and health) and business. For access to improved cookstoves, we assess impacts on household welfare. The reviewed literature highlights a significant causal impact of electricity access on important metrics of wellbeing, but more mixed evidence regarding clean cookstoves. Finally, we also review the barriers and drivers of access to modern energy services identified by most recent impact evaluation studies.

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Keywords: Impact Evaluation, Energy Poverty, Energy Access, Rural Electrification, Modern Cookstoves, Literature Review
JEL Classification: O1, O13, Q4, Q48

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Access to modern energy: a review of impact evaluations

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Abstract
Universal access to modern energy services, in terms of access to electricity and to modern cooking facilities, has been recognized as fundamental challenge for development and is likely to be included in the post-2015 Sustainable Development Goals. Despite a strong praise for action and several programs at both national and international level, very few impact evaluation studies try to shed light on the causal relationship between access to energy and development, by also allowing decision makers to rigorously assess cost-effectiveness and efficiency of policies and programs. This work attempts to review the literature on existing impact evaluation of access to electricity and modern cooking facilities. For access to electricity we consider as outcomes labour markets, time allocation, household welfare (consumption, income, schooling and health) and business. For access to improved cookstoves, we assess impacts on household welfare. The reviewed literature highlights a significant causal impact of electricity access on important metrics of wellbeing, but more mixed evidence regarding clean cookstove. Finally, we also review the barriers and drivers of access to modern energy services identified by most recent impact evaluation studies.

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1. Stylized facts

Energy poverty is defined as lack, scarcity or difficulty in accessing modern energy services by households, in particular it refers to the access to electricity and to modern and clean cooking facilities. The International Energy Agency estimates that currently 1.26 billion people (18% of

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worldwide population) lack access to electricity and 2.64 billion (38% of global population) rely on traditional cooking methods based on the use of biomass with severe consequences on health due to indoor air pollution (IEA 2013).The geographical distribution of such phenomena is not even across the world: 84% of people lacking access to modern energy services live in rural areas; people without electricity are mostly in developing Asia (51%) and Africa (44%), similarly those still relying on traditional cookstoves and fuels are concentrated in developing Asia (72%) and Africa (25%). According to the IEA's scenarios, the situation will not change significantly by 2030: about 1 billion people will still lack electricity, with strong improvements in Latin America, Middle East and developing Asia but no progress in Sub-Saharan Africa. 2.5 billion people will still rely on biomass for cooking, basically with no progress in absolute terms with respect to the current situation.

The World Health Organization estimates that the use of traditional methods of cooking, through wood and biomass combustion, has severe consequences on the health of households, due to indoor air pollution. The recent Global Burden Disease study estimates that almost four million people die every year from indoor air pollution due to the use of traditional cooking fuels and stoves (Lim et al. 2013, Martin et al. 2011). Moreover, the extensive use of wood as main energy fuel impacts the local environment, due to deforestation, soil degradation and erosion. At global level, inefficient biomass combustion is a major determinant of black carbon, a contributor to global climate change.

In the light of such imbalances several policies have been proposed as a way to improve access to energy. In order to test different policy designs, experimental research projects have been deployed worldwide. The main contribution of this paper is to review the available evidence emerging from this recent literature, by framing it into the overall policy context. To do so, we begin by introducing the main objectives identified in the international agenda in order to fight energy poverty at global level; some case studies of rural electrification programs and initiatives for the diffusion of improved cookstoves at national level are briefly sketched and assessed. The third section focuses on the impacts of access to electricity and improved cookstoves on household welfare and reviews the main contributions on the impacts on health, labour market outcomes, female empowerment and business. The main barriers which prevent access to electricity and adoption of improved cookstoves and the major drivers of diffusion are also reviewed. The fourth section sketches the main impacts and consequences of universal access policies at macro level and reviews the results of scenario studies.

2. Policies for fighting energy poverty

2.1 The international agenda

Sustainable energy development enters the international inter-governmental agenda for the first time at the United Nations General Assembly in 1997. In 2000 the World Energy Assessment first addresses the nexus among energy, social issues, health and environment in a general context of energy access and security, efficiency, particularly at rural level. It first depicts energy scenarios. Several following international appointments set energy sustainability as a priority for global development: Ninth Session of the Commission on Sustainable Development in 2001, World Summit on Sustainable Development (WSSD) in Johannesburg in 2002. In the latter energy access is recognized as a crucial aspect for the achievement of the Millennium Development Goals, calling for the implementation of sustainable patterns of energy production and use. In 2010 the Advisory

Group on Energy and Climate Change to the United Nations' Secretary-General proposes to the international community a set of energy-related goals (AGECC 2010), summarized by the universal energy access by 2030. 2012 is declared the International Year of Sustainable Energy for All by the UN General Assembly, in order to catalyze global attention and commitment on these topics. In 2012 the SEFA - Sustainable Energy for All – program is launched, as one of the results of the Rio+20 Conference. Its main goal is to assure universal access to modern and sustainable energy by 2030, improving the rate of renewables in the energy mix and promoting energy efficiency. The objectives are to increase renewable energy which currently constitutes 15% of the global energy mix to 30% and to double the global rate of improvement in energy efficiency by 2030.
SEFA states clearly that the cooperation among research, private and public sector is the key to achieve this goal. Despite the praise for action, it is still unclear which public and private initiatives and policy design can be used to best attain the goals of energy poverty eradication.

2.2 Rural electrification programs

There are large variations in electrification rates across and within regions. According to the World Energy Outlook 2011 (IEA, 2011) transition economies and countries belonging to the OECD have almost universal access. North Africa has an access rate of 99%, Latin America 93,2%, China and East Asia 90,8%, and the Middle East 89%. By contrast, South Asia has an electrification rate of 68.5 and Sub-Saharan Africa only 30,5%. People without electricity in these two regions are 493.4 million and 585.2 million, respectively, accounting for more than 80% of the total world population without electricity (IEA, 2011). Some countries have made progress in connecting remote rural areas to electricity. In particular, several emerging economies have included rural electrification programs in their socio-political agenda in order to reduce the strong existing urban-rural divide, as electricity is thought a driver of living standards improvements. Some example of large national rural electrification programs are represented by Brazil, China and India which have achieved more than 65% electrification rate through significant public investments[2].
For example, Brazil since 2003 have run the national program for rural electrification "Luz para todos" which enabled to connect more than 14.5 million individuals by 2011 and to reduce the share of people disconnected from electricity to less than 2%, mostly concentrated in the Amazon region which is not connected to the integrated grid transmission system. The program have been realized through the cooperation of the central government, the holding company of the Brazilian electricity, the utilities and rural electrification co-operatives. The program required investments in grid expansion (approximately $7 billion) and an increase in generating capacity which have been relatively inexpensive due to the presence of large hydroelectric power stations (Niez, 2010). People benefited from electricity connection free of charge and social tariffs with discounts decreasing (from 65%) as energy consumption increases.
Another example of strong political commitment towards universal electricity access is China where in 2009 only 8 million people lacked access to electricity (in 1976 it was 50% of the population) (IEA, 2011). This was possible through a great effort of the government in the development of the grid and the increase of power generation using primarily coal and distributed small hydroelectric stations. Recently, China made effort in introducing renewable energy programs both in rural and urban areas. However, problems related to

[2]For a more detailed overview of the electrification programs in emerging countries, see Niez (2010)

the quality of electricity supply, the role of private sector, pricing of energy and long-run maintenance investments remain unresolved problems.

In 2005, a total of 412 million people in India had no access to electricity, with 380 million of them (92% of total population) living in rural areas and 32 million in urban areas (IEA, 2007). According to the Census of 2011, India is 67.2% electrified, with an urban electrification rate reaching 92.7% and a rural rate of only 55.3% (Census 2011, Government of India). The challenge of rural electrification has been faced through the government-led Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) scheme and the Remote Village Electrification Programme since 2005. The first scheme was meant to reach all rural un-electrified household through grid extension, allowing poor people to connect for free[3]; the second one aimed to complement the previous program with measures for the provision of basic lighting/electricity facilities through renewable energy sources. In 2013, 32,227 villages of India are yet to be provided with electricity[4] access which correspond to 5.4% of Indian villages (Central Electricity Authority).

International institutions and regional development banks have collaborated with governments to projects of rural electrification. For example, the World Bank supported more than 120 projects since 1980, particularly in Latin America and Sub-Saharan Africa, by supporting the growth of off-grid electrification using renewable energy technologies. Most of such projects aimed to increase the energy supply, through infrastructure development, rather than explicitly target poverty issues (IEG, 2008).

Once universal access to electricity is set among governments' priorities[5], the challenges which need to be tackled, particularly in underdeveloped rural areas, relate to key strategic policy decisions regarding electricity generation, transmission and distribution, costs, affordability and regulation.

Energy generation looks at the energy mix maximizing country energy supply unexploited potential, among traditional and renewable resources. Allowing access to electricity for large shares of rural population requires increases in electricity supply by investing in new generation plants employing different resources, depending on individual countries' advantages. For example, China responded to the increase in demand by expanding electricity generation through coal thermal plants (IEA, 2011). It is estimated that solar and hydro power could meet a large part of Africa's future electricity needs. Wind and geothermal power can also contribute significantly in some areas (Sanoh et al. 2014).

Another important aspect is related to the distribution of energy supply. Grid extension remains one of the most common means of universal electrification, given the advantages derived from economies of scale in energy production. However, rural electrification is not as rentable as urban areas and strong commitment by governments is usually required. Alternatively, mini-grids can be installed when the grid extension option seems too expensive or as back-up energy source in order to prevent the serious consequences of outages to key infrastructures such as hospitals or important firms; technical options include, for example, small hydro, biomass-powered generators, small geothermal, solar photovoltaics (PV), solar thermal, wind turbines, and hybrids consisting of more than one technology (with the possible inclusion of fossil-fuel-powered generation.). All small,

[3] Tariffs vary from state to state and in some cases are based on metered supply in other are flat.

[4] A village is deemed electrified, if 10 percent of all the households of the village has electricity access and if electricity provided to public spaces such as schools, panchayat officers, health centres, community centres and dispensaries.

[5] About half of developing countries have declared electricity access target at national, urban and rural level. Less than 15% have set targets for access to modern cooking fuels or improved coockstoves (IEA, 2010)

community-wide electric systems – whatever resource they use - are dependent on a local distribution grid to transmit energy from the source to the consumer. Dispersed renewables energy options using small-scale, renewable energy systems, including solar photovoltaics and wind turbines, are reliable and cost-competitive options for electrification of households in dispersed or isolated communities[6]. The realization of such electricity infrastructures, particularly large-scale ones, may require a direct commitment of governments both in terms of direct investments and of promotion of private-sector partnerships and investments, through adequate institutional infrastructures and regulation.

The effort to universal access should balance the necessary long-term sustainability of projects, essential in order to attract private investments, with the issue of access and affordability of the poorer. Affordability relates to the capability of household to be financially and economically capable to access and use electricity. Progressive tariffs, lifeline tariffs (households consuming below a certain amount per month receive a subsidy), innovative financing solutions, for example through microcredit, are among the possible tools governments can adopt to help access and use of electricity by rural and poor households (Winkler et al. 2011).

2.3 Initiatives for adoption of improved cookstoves

The implementation of policies at national level aimed to improve cooking strategies and avoid health problems related to high exposure to IAP have followed three main strategies. The first one tried to promote cleaner fuel adoption through the substitution from biomass to kerosene and LPG. This has been the case for Ecauador and Indonesia, where poor households could benefit from subsidized kerosene for cooking (Barnes and Helpern, 2000). However, drawbacks emerged such as the high cost of kerosene and LPG and difficulties to supply them in remote areas, given poor infrastructure. More recently, a second practice has seemed to prevail, the development and promotion of improved cooking stoves which use wood and biomass in a more efficient way while reducing exposure to air pollutants through the introduction of a chimney. The important pros of the the substitution of cookstoves rely on the fact that the technology is relatively easy to up-scale using local materials and producers (which may also increase job creation in the area and the use of local materials), prices are affordable even for poor households and the final product is similar to traditional cookstoves, allowing to minimize the cultural "gap" derived from the introduction of a new technology. A third option is the introduction of small scale bio-digester for the production of biogas at community and household level, though a wide diffusion of such technologies has been slow in several developing countries[7].

Several emerging countries are developing initiatives for the diffusion of improved cookstoves for the large proportion of households still relying on traditional technologies. For example, India launched several programs since 2006-07 to promote biomass pellets stoves and more efficient ceramic stoves employing wood, however no subsidy to the purchase was envisaged. In 2009 the National Biomass Cookstoves Initiative was started on a larger scale (Venkataraman et al. 2010).

Since early 1980s China launched a national program for the dissemination of efficient and improved coal stoves (with chimney) at subsidized prices which led to rapid stove dissemination. After 1990 the subsidy was suspended and households bore the entire burden of the purchase

[6] For a review and classification of available systems and technologies, see Mandelli and Mereu (2013)

[7] For a review and classification of available cookstove and biogas technologies, see Mapelli and Mungwe (2013)

(Sinton et al. 2004). China is reported to be able to distribute over 35 million improved cookstoves over the last decades (Duflo et al. 2008).

Looking at some African cases, through joint government, donor, and NGO effort, Kenya distributed around 1.5 million improved stoves (over twenty years) at prices ranging from $1.5 to $6.5 and Ethiopia distributed a similar number of improved charcoal stoves (over ten years) at $2-$4. (Duflo et al. 2008; World Bank 2010).

In September 2010, Hillary Clinton announced the formation of the Global Alliance for Clean Cookstoves (GACC), which calls for 100 million homes to adopt clean and efficient stoves and fuels by 2020 and aims to draw the international attention on this issue, by mobilizing support from a wide range of private, public and non-profit stakeholders at global level.

Despite such praise for action, improved cookstoves diffusion is not part of the agenda of interventions by international agencies like the World Bank: in 2011 less than 20 World Bank financing of improved stove projects were supported, mainly in Sub-Saharan Africa (World Bank, 2011). However, we acknowledge that the actual impacts on health and welfare of the introduction of improved cooksotves out of laboratories is still debated in the literature, as described in section 3.12.

3. Access to modern energy services and development

Energy access, the so-called “Missed MDG”, intended as access to electricity and modern cookstoves, is considered a fundamental driver of economic and social development. It is a crucial determinant of health and a key condition to guarantee access to clean water, sanitation, schooling and business in developing countries (Modi et al. 2006). In the words of UN Secretary General, Ban Ki Moon, "Universal energy access is a key priority on the global development agenda. It is a foundation for all the Millennium Development Goals". In the light of this new awareness, universal energy access has been proposed and should be included in the Sustainable Development Goals, given “the critical role that energy plays in the development process, as access to sustainable modern energy services contributes to poverty eradication, saves lives, improves health and helps provide basic human needs”, as expressed in the Rio+20 outcome document.

Access to modern energy services may allow reallocation of household time (especially by women and children) from energy provision to improved education and income generation. People can also benefit from greater flexibility in time allocation through the day and evening derived from better lighting. When combined with other infrastructures, access to modern energy services allows lower transportation and communication costs, favours a better access to markets and information. Access to electricity may also improve rural productivity, due to the introduction of technology and therefore may directly contribute to household income and push labour supply in non-agricultural activities. However, the strong correlation between energy access and development indicators does not necessarily implies causal relationship. The distribution of infrastructure projects is subject to political decisions which may be selective towards particular areas: projects can be targeted towards growing or politically relevant areas; in rural areas, richer villages are probably more likely to be connected to the grid than poorer ones. Finally, the probability of being connected depends on other factors such as the distance to big cities, population density and geographical characteristics of the area. Such selectivity generates program placement bias which prevents researchers from a clear evaluation of the effects of energy access, for example through the comparison of the development outcomes of electrified and non-electrified areas. Confounding trends in the economy make it even more difficult to tease out the effects of infrastructure on any economic outcomes.

3.1 Impacts of access to modern energy services

Despite of the great effort on rural electrification programs by governments and international agencies, relatively limited evidence assesses the benefits to household welfare derived from electric connection in a rigorous way (IEG, 2008). By rigorous we define a minimum standard in terms of identification strategies and estimation techniques. In what follows, we try to survey the most relevant attempts in this direction. In particular, we include studies which assess the causal relationship between access to electricity and different outcome variables trying to solve the issues of reverse causality, endogeneity and selection bias through rigorous estimation design such as instrumental variable (IV) estimation, difference in differences (D-D), by exploiting natural experiments, panel data analyisis, fixed effects (FE) estimations, randomized control trials (RCT) and propensity score matching (PSM).

3.1.1 Electricity

Labour market

Some studies look at the causal nexus between electrification and different economic and social outcomes. The impact of electrification on labour market outcomes seems to be one of the more robust, although still not definitive, and given its importance we begin by reviewing it. Table 1 reports the most important contributions on the causal effects of access to electricity on labour market outcomes, specifically employment rate, labour supply and wages and earnings. The table also provides the geographical region where the microeconomic study has been carried out and the estimation techniques employed to identify the casual effect.

Regarding employment, Dinkelman (2011) shows significant rise in female occupation (9 to 9.5% increase) and number of worked hours for female in rural areas of South Africa which can be attributed to the access to electricity. The mechanism allowing the improvement of female labour market conditions lies in the substitution of time devoted to firewood collection with more advanced technology for cooking and lighting. The time saved is then spent in income generating activities (e.g. small business and cottage industry). Libscomb et al. (2013) also find strong effects on activity rates and formal employment both in rural and urban areas of Brazil. Regarding labour supply, the evidence seems to indicate an increase in the medium and long run in several studies across different regions. Grogan and Sadanand (2013) consider a sample of rural households in Nicaragua: rural electrification increases the probability that women are employed in non-agriculture activities outside the household. Similarly, Dasso and Fernandez (2013) find increases in hours of work for men and higher earnings derived by more intensive non-agriculture activities for women in rural Peru. Dinkelman (2011) finds significant increases in labour supply for both women and men in South Africa. Van de Walle et al. (2013) detect significant substitution effects from irregular and casual works to the formal sector for men in India. Higher quality electricity provision by private providers compared to public one seemed to lead to a reduction of hours worked in agriculture (Torero et al. 2007). However, Bernard and Torero (2014) find no short-run effect of rural electrification on time spent on income generating activities at household level.

The evidence of the effects of electricity on wages does not seem to be conclusive on the existence and strength of impacts. For example, Dinkelman (2011) finds higher earnings for men (not for women) but no average effects on wages. Similarly Khandker et al. (2013) show significant increases in household incomes, via improvements in non-agricultural activities, and no effect on wages. Increases in non-agriculture income are also supported in studies by Dinkelman et al. (2011) and Lipscomb et al. (2013). Reductions in electricity outages and increases in hours per day generate relevant improvements in non-agricultural incomes in rural India (Chakravorty et al. 2013).

Table 1. Casual effects of access to electricity on labour market

Outcome	Results	Study, geographical region	Method	Sample size (level)	Period (n. of time obs)
Employment rate	Electrification leads to a 9 to 9.5% increase for women and no significant effect for men	Dinkelman (2011), South Africa	D-D with IV	1816 (community)	1996-2001 (2)
	Strong effect on activity rate and employment in the formal sector, both in rural and urban areas	Libscomb et al. (2013); Brazil	FE - IV	2184 (county)	1960-2000 (5)
Labour supply	Significant increase in the propensity (+23%) to work outside the home for wome. No effect for men	Grogan and Sadanand (2013); Nicaragua	IV	6882 (household)	1971-2005 (3)
	No short run effect of rural electrification on time spent on income genereting activities	Bernard and Torero (2013), Ethiopia	RCT with encoruragement design	563 (household)	(2)
	Increase for both women and men (only OLS)	Dinkelman (2011), South Africa	pooled OLS & FE	1816 (community)	1996-2001 (2)
	Significant substitution of days of work from casual wage works to regualar wage and agriculture self-employment for men. Small significant reduction of female causal wage work.	van de Walle et al. (2013); India	Panel data & IV	~3000 (household)	1981-1999 (2)
	Small increase in hours worked for men, no effect on women. Decrese probability to be self-employed for women (nothing for men). Decrease in the likelihood of having more than one job among males	Dasso and Fernandez (2013); Peru	DD and FE	246,735 / 12,964* (household)	2006-2012 (6)
Wages & Earnings	No significant effect on wages. Higher earnings for men, no significan impacts for women	Dinkelman (2011), South Africa	pooled OLS & FE	1816 (community)	1996-2001 (2)
	Significant increase in total hh income, due to the increase in non-agricultural income. No effect on wages	Khandker et al. (2013); Vietnam	Panel data &FE	1120 (household)	2002-2005 (2)
	Suggestive evidence of increase in income	Bensch et al. (2011), Rwanda	PSM	531 (household)	2005 (1)
	Strong effect on household income	Libscomb et al. (2013); Brazil	FE - IV	2184 (county)	1960-2000 (5)
	Strong effect on household non-agricultural income. Also the quality of electricity (frequency of outages) matters for hh income	Chakravorty et al. (2014); India	FE - IV	9791 (household)	1994-2005 (2)

Household welfare

Recent works find that access to electricity bears positive effects on household welfare, in terms of income, consumption, behavior at cooking and lighting, time allocation of house activities, schooling and health.

Only few studies assess the influence of electricity on levels of consumption and expenditure: Khandker et al. (2013) find that rural access to electricity in Vietnam leads to an increase in consumption expenditure of 23%. Similarly van de Walle et al. (2013) show that access to electricity in India led to a significant increase in total expenditure, particularly for food, fuel and kerosene stoves. Changes in the use of sources of light and cooking are found in other contexts: Bensch et al. 2011 find significant increases in lighting hours and energy expenditure in Rwanda; similarly Dinkelman (2001) show that access to electricity led to a large increase in the use of electricity for lighting and to, a lesser extent, the substitution of cooking habits: from wood to electricity.

Several works lead to the conclusion that access to electricity has an impact on the way people allocate their time, as a consequence, for example, of the decrease in time collecting biofuels for adults in India (Khandker et al. 2012), but it also influences important changes in children life, particularly on time dedicated to study and schooling. Positive effects of household electrification have been shown on enrolment and years of schooling for Indian girls (van de Walle, 2013). In other studies by Khandker et al. (2012, 2013) and Lipscomb et al. (2013) such results are confirmed for both boys and girls in India, Vietnam and Brazil. Children study time outside school seems to increase in some studies (Khandker et al. 2012, Bensh et al. 2011), however no short run effects on children study time or spent collecting wood are found by Bernard and Torero (2014) in a randomized study on rural electrification in Ethiopia.

The impact of electrification is not limited to the rural household which is connected to the grid, but has externality effects to other non-connected villagers. Benefits of rural electrification are shown to spill over households not connected to the grid, which have higher level of consumption compared to non-connected households (van de Walle et al. 2013). The externality effect of electricity operating through the community is also confirmed in Burlando (2014) where villages affected by a long power outage, regardless of their level of electrification, experienced similar significant increases in births.

Health

Electrification can bring indirect benefits to rural communities and households health when it contributes to the improvement of health infrastructure and of health-care quality. However, health effects can also be direct, at household level. Electrification seems to lead to the substitution of kerosene lighting with electric light, allowing significant and steady over time reductions in overnight $PM_{2.5}$ concentration. This turns out to provide substantial welfare improvements in terms of falls in acute respiratory infections among children under 6 (Barron and Torero, 2013).

The introduction of electricity also seems to negatively affect fertility (Grimm et al. 2014, Burlando 2014, Fetzer et al. 2013). The main channels through which electricity reduces fertility are exposure to the media, often promoting family planning campaigns, the reduction of child mortality and the possibility to allow people to gather and have leisure time together during evenings.

An impact evaluation analysis of electrification on a wider set of outcome indicators and for a larger time span is provided by Lipscomb et al. (2013) for Brazil. The authors show the positive impact of electrification on measures of development such as the Human Development Index (HDI), which include indicators referring to income, schooling and health. The improvement in HDI as consequence of access to electricity are mainly led by the income and schooling component.

Table 2. Casual effects of access to electricity on household welfare

Outcome	Results	Study, geographical region	Method	Sample size	Period (n. of time obs)
Consumption and expenditure	Significant increases in total consumption expenditure, particluarly for food and fuel. Significant increase in the purchase of kerosene stove	van de Walle et al. (2013); India	Panel data & IV	~3000 (households)	1981-1999 (2)
	23% increase in household expenditure	Khandker et al. (2013, EDCC); Vietnam	Panel data & FE	1120 (household)	2002-2005 (2)
Lighting	Strong significant effects on lighting hours, increase in energy expenditure	Bensch et al. (2011), Rwanda	PSM		
	Large significant increase in the use of electricity for Lighting	Dinkelman (2011), South Africa	D-D with IV	1816 (community)	1996-2001 (2)
Cooking behaviour	Small significant decrease in in propensity to cook with wood	Dinkelman (2011), South Africa	D-D with IV	1816 (community)	1996-2001 (2)
	Small significant increase in propensity to cook with electricity	Dinkelman (2011), South Africa	D-D with IV	1816 (community)	1996-2001 (2)
Time collecting biofuel	Large significant decrease in time collecting biofuel for women and men. Small slightly significant for boys. No effect on girls	Khandker et al. (2012), India	IV	~24000 (households)	2005 (1)
Schooling	Significant positive effects of household electrification on enrollment and the average years of schooling as a share of the maximum possible for a given age, only for girls.	van de Walle et al. (2013); India	Panel data & IV	~3000 (households)	1981-1999 (2)
	No short run effect of rural electrification children study time	Bernard and Torero (2013), Ethiopia	RCT with encoruragement design	563 (household)	(2)
	Significant increase in school enrolment, time spent studying and years of completed schooling for both boys and girls	Khandker et al. (2012), India	IV	~24000 (households)	2005 (1)
	Significant increase in school enrolment and years of completed schooling for both boys and girls	Khandker et al. (2013, EDCC); Vietnam	Panel data & FE	1120 (household)	2002-2005 (2)
	Small positive effects on the kids studying at home indicator	Bensch et al. (2011), Rwanda	PSM	531 (household)	2005 (1)
	Strong effect on literacy and enrolment: increase in year of schooling (+2 years)	Libscomb et al. (2013); Brazil	FE - IV	2184 (county)	1960-2000 (5)
HDI	Strong significant effect of electrification on HDI (also on average value of the housing stock) over 40 years. Improvements are concentrated in the education and	Libscomb et al. 2013); Brazil	FE - IV	2184 (county)	1960-2000 (5)

	income (no effects on health) components of HDI				
Health					
Indoor air pollution	Large significant reduction of PM2.5 concentration, due to less kerosene consumption for lighting	Barron and Torero (2013), El Salvador	RCT with encouragement design	486 (household)	2009-2012 (4)
Acute respiratory infections	Large significant reduction of acute respiratory infections among children under 6 (self-reported)	Barron and Torero (2013), El Salvador	RCT with encouragement design	486 (household)	2009-2012 (4)
Fertility	Positive short-run effect of electricity outage on fertility	Burlando(2014), Zanzibar	DD, natural experiment	125 (village)	2007-2009 (weekly)
	Positive short and long-run effect of electricity outage on fertility	Fetzer et al (2013), Colombia	DD, natural experiment	~60000 (woman)	1990-2005 (3)

Business

Poor electricity infrastructures are considered among the most relevant barriers to economic growth, particularly for the development of industrial activities which heavily rely on the quality supply of electricity. The lack of quality and reliable electric infrastructures lead firms to self-generate energy, often with consequent higher costs. This is the case for several developing countries, particularly in Africa (Alby et al. 2011; Steinbucks and Foster, 2010; Foster and Briceño-Garmendia, 2010). Table 3 reports the most important contributions on the casual impact of access to electricity on the business outcomes. Rud (2012) studies the effects of the impact of the expansion of access to electricity on industrial growth in India and finds positive impacts on production levels and number of industrial activities, at regional level. An increase in the number of small manufactory activities as a consequence of electrification is also documented in Benin, though no effects on profits are found (Peters et al. 2011). Low quality electricity infrastructures, reflected by frequent shortages, have negative effects on revenues and productivity, due to higher energy costs. The effect is stronger for small firms, which are less likely to own generators to cope with shortages (Alcott et al. 2014, on Indian data). Losses in productivity due to unreliable electricity supply for industrial firms are also observed in China (Fisher-Vanden et al. 2012). Unreliable and inadequate electric power supply also contributes to the reduction of investments in productive capacity by firms (Reinikka and Svensson, 2002 on a survey of Ugandan firms). Ryan (2013) finds that investments for the expansion of electric transmission infrastructures allowing for more capacity and eventually improving the quality of electricity supply would lead to large welfare gains, due to higher competition on the market.

Table 3. Causal effects of electricity on business activities

Results	Study, geographical region	Method	Sample size (unit)	Period (n. of time obs)
1% increase in shortages generates 0.68% decrease in revenues in the short run. Stronger effects on smaller plants (less likely to own generators)	Allcott et al. (2014); India	D-D with IV	~3000 (manufact. firms)	1992-2011 (20)

No significant differences in profits between connected and non-connected firms, after matching	Peters et al. (2011); Benin	PSM	276 (manufact. firms)	2008 (1)
Increase in rural connections generates large increases in manifacturing output	Rud (2012), India	D-D with IV	16 (state)	1960-1985 (25)
No effect of shortages on TFP in the short run	Allcott et al. (2014); India	D-D with IV	~3000 (manufact. firms)	1992-2011 (20)
Increase in rural connections generates increases in the number of (small) firms	Rud (2012), India	D-D with IV	16 (state)	1960-1985 (25)

Note: DD: Difference in Differences estimation; IV: Instrumental Variables estimation; RCT: Randomized Control Trial; OLS: Ordinary Least Square estimation; FE: Fixed Effect estimation

3.1.2 Improved cookstoves

WHO claims that the use of traditional cooking stoves and fuels such as firewood and biomass has severe consequences on health, through air pollution in the house. Pneumonia and hearth diseases, whose indoor smoke inhalation is among the underlying causes (Ezzati and Kammen, 2001), are some of the most important burden of global diseases. It is estimated are about 4 million deaths yearly due to household indoor air pollution (Lim et al. 2013, Martin et al. 2011). Such numbers are greater than deaths from malaria, HIV/AIDS and tubercolosis (WHO 2008) which are expected to decrease substantially by 2030, whereas respiratory diseases leading to death due to indoor air pollution, at the current pace, are not expected to reduce. Health consequences of indoor air pollution are particularly severe on women and children (Smith et al. 2004).

The use of modern and improved cooking stoves may have positive consequences on household welfare and sustainable development, from several points of view: health, female empowerment and environment. For example, inefficient stoves require more time to cook and gather fuel, a task mainly addressed by women and children, who divert time from education and income-generating activities, although these aspects are strongly related to cultural and behavioural traits which are different from place to place and may eventually slow changes in households habits after the introduction of the new technology. From the environmental point of view, inefficient stoves may influence ambient air and local forest ecosystems.

Despite the strong international commitment and numerous initiatives promoted by the private and public sector in order to reach the goals of universal access to energy, very few studies rigorously investigate the efficacy of programs and policies. In what follows, we try to survey the most relevant attempts in this direction.

Health

Arguably, the most important channel through which the use of improved cookstove impacts on individuals and households is through the limitation of indoor air pollution (IAP). Despite of the great variety of products which could be defined improved cookstove (World Bank 2010), the simple introduction of firebox and chimneys allow important improvements in terms of IAP, compared to traditional stoves (open or three stone fires). For example, Dutta et al. (2007) find reductions of carbon monoxide concentration by 38% and of PM2.5 concentration by 24 to 49%. This reduction is shown to have beneficial effects on health. Several studies seem to convey that changes in cooking technologies reduce the incidence of acute respiratory infections and lung capacity. In general, a large strand of the literature in epidemiology and environmental science supports the existence of a strong positive association between IAP and negative health outcomes (Zhang and Smith, 2007), however most evidence relies on observational studies and is unable to identify a proper casual effect: the choice of cooking fuel and stoves may be related to unobserved health behaviour which also affects health outcomes. For example, better respiratory health in households that cook with cleaner fuels may be due to better access to information on health prevention which may also impact on other health-related behaviours (Duflo et al. 2008). Moreover, much of the studies do not consider the possible mitigation of the reduction in smoke inhalation due to behavioural responses of people who not necessarily may properly use and maintain cookstoves over time, after the first wave of promotion and distribution.

Only a handful of studies evaluate the health impacts of the adoption of improved cooking stoves using randomized control trials on the field. The project RESPIRE (Randomized Exposure Study of Pollution Indoors and Respiratory Effects) is a medical experimentation on respiratory consequences of indoor air pollution and on the potential benefits from the introduction of more modern techniques in Guatemala. The use of improved cookstoves reduced carbon monoxide exposure by 50 to 60%, with consequent significant reductions in risk of respiratory disease, such as pneumonia, over the 18 months following the distribution of cookstoves (Smith et al. 2011; Smith-Sivertsen et al. 2009). Another studies in India based on longer time span show that the effects of the introduction of modern cooking stove have only modest health effects which tend to vanish in the longer period (Hanna, Duflo and Greenstone, 2012). This is mainly due to the fact that not always the use of such new technologies is continued in time and maintenance is often neglected. A partial confirmation of such problems is provided by Simons et al. (2014) who find significant Hawthorne effects[8] around the periods of cookstove performance measurement by researchers and draw the attention on normal household behaviour. Dherani et al. (2008) use meta-analysis and find that that risk of pneumonia in young children is increased by exposure to unprocessed solid fuels by 80%. Using different non-experimental techniques, other studies highlight the causal relationship between modern cooking stoves and health improvement (among several, Ezzati and Kammen, 2002, Ezzati et al. 2000, Silwal and McKay, 2013, Gajate-Garrido, 2013, Mueller et al. 2013, Yu 2011).

Household welfare

Rigorous evidence on the role of improved cookstoves on time allocation, female and children conditions is quite scarce (Kohlin et al. 2011). In rural areas, the collection of firewood, often performed by women and school-going children, takes time away from other productive pursuits, such as income generating activities and education (Barnes and Toman 2006). Charmes (2006) analyses time use in several Sub-Saharan Africa, by looking at large-scale surveys, and finds that that women spend 3-5 times as much time as men on domestic activities like collecting firewood and cooking. However, if we look at the two activities separately, it turns out that the picture is more balanced between men and women for firewood collection, whereas cooking activities are largely dominated by women. Bensch and Peters (2012) find that the use of improved cookstoves causes a significant reduction of about one third in the amount of firewood necessary for cooking

[8] The Hawthorne effect is when individuals change an aspect of their behavior in response to their awareness of being observed

which resulted to be shorter, with consequent time saving and decrease in stated respiratory diseases. Similarly Belthramo and Levine (2013) show slight declines in wood use in large Senegalese households, after the introduction of solar ovens. Though, no effect on time dedicated to wood collection was found. This result is corroborated by Bruwen and Levine (2012) in a study on Ghana and by Hanna et al. 2012 in India, where no effect on wood use and expenditure was found.

Table 4. Causal effects of improved cookstove adoption on health and household welfare

Outcome	Results	Study, geographical region	Method	Sample size (level)	Period (n. of time obs)
Health					
Respiratory disease	No ITT effect of chimney stoves on physician-diagnosed pneumonia. Positive effect of fieldworker assessed severe pneumonia	Smith et al. (2011); Guatemala	RCT	534 (household)	2002-2004 (weekly)
	No ITT effect on lung functioning (measured with spirometry) and self-reported measures	Hanna Duflo and Greenstone (2012); India	RCT	2651 (household)	2005-2010 (2)
	Significant effect on self-reported symptoms of respiratory diseases and eye problems	Bensch and Peters (2012); Senegal	RCT	253 (household)	2009-2010 (2)
	Significant decline in self-reported symptoms associated with cooking	Bruwen and Levine (2012); Ghana	RCT	488 (household)	2009 (2)
	No effect on self-reported symptoms associated with cooking	Belthramo and Levine (2013); Senegal	RCT	790 (household)	2008 (2)
Exposure to air pollution	50% carbon monoxide exposure reduction of for children, 60% for women	Smith et al. (2012); Guatemala	RCT	534 (household)	2002-2004 (weekly)
	7.5% carbon monoxide exposure reduction in the first year. No effect in the longer run (no particular reductions for children and women)	Hanna Duflo and Greenstone (2012); India	RCT	2651 (household)	2005-2010 (2)
	No effect on carbon monoxode exposure	Bruwen and Levine (2012); Ghana	RCT	488 (household)	2009 (2)
	No effect on carbon monoxode exposure (measured on a small sub sample)	Belthramo and Levine (2013); Senegal	RCT	790 (household)	2008 (2)
	90% decrease in carbon monoxide concentration	Smith et al. (2012, Lancet); Guatemala	RCT	534 (household)	2002-2004 (weekly)
	no evidence of a reduction in greenhouse gas emissions	Hanna Duflo and Greenstone (2012); India	RCT	2651 (household)	2005-2010 (2)
		Household welfare			
Time spent cooking	No effect on time for cooking	Hanna Duflo and Greenstone (2012); India	RCT	2651 (household)	2005-2010 (2)
	Significant 20% reduction in dayly cooking time	Bensch and Peters (2012); Senegal	RCT	253 (household)	2009-2010 (2)
time spent for firewood collection	No significant effect on time spent collecting wood	Bensch and Peters (2012); Senegal	RCT	253 (household)	2009-2010 (2)
	No effect on time spent for wood collection and time of cooking (solar ovens)	Belthramo and Levine (2013); Senegal	RCT	790 (household)	2008 (2)
Fuel use and expenditure	No effect on wood use and expenditure	Hanna Duflo and Greenstone (2012); India	RCT	2651 (household)	2005-2010 (2)
	Significant reduction in wood consumption (30% weekly)	Bensch and Peters (2012); Senegal	RCT	253 (household)	2009-2010 (2)

No effect on wood use	Bruwen and Levine (2012); Ghana	RCT	488 (household)	2009 (2)
Solar ovens cause only slight decline in wood use only for numerous households,	Belthramo and Levine (2013); Senegal	RCT	790 (household)	2008 (2)

3.2 Barriers and drivers to access to modern energy

3.2.1 Electricity

Reaching rural villages with electricity does not always necessarily means connections for all households, as connection to the grid may be expensive. Very few papers assess the role of barriers and drivers to the connection to the grid/mini-grid. The individual decision to connect seems to be linked to the price of connection which may range between $50 and $250; despite subsidization, such fees may result prohibitive for most poor households. For example, in Ghana and South Africa while less than 5% of the poorest rural housholds were connected to electricity, those in the richest quintile were more than 20% (Heltberg, 2003). By randomly allocating 10 and 20% discount vouchers for connection fees to rural Ethiopian households, Bernard and Torero (2014) find that connections increase, on average, by 18%, revealing that connection fees represent a significant barrier to the adoption of electricity. Low connection rates have been also linked to low levels of understanding of payment system or limited knowledge of the potential advantages of electricity (Ranganathan, 1993). A third relevant channel in household decision-making towards electricity connection is others' connection behaviour. Bernard and Torero (2014) find evidence of *bandwagon* effect: connection to electricity carries a social status so that neighbours' connection decisions have impact (decreasing in distance) on household connection decision.

3.2.2 Improved cookstoves

The works on barriers and drivers of adoption and use of improved and healthier cookstoves is strongly connected to the literature on health seeking behavior in developing countries, related to the adoption of preventive and remedial practices and products which are very effective in reducing the burden of morbidity and mortality, such as malaria, HIV/AIDS, waterborne and respiratory diseases (Dupas, 2011b). Insecticide treated bednets, water treatments with chlorine, condoms, menstrual cups and deworming pills are among possible relatively easy and inexpensive solutions whose take-up results quite slow, though. The role of subsidies and price to mitigate liquidity constraints (Ashraf et al. 2010, Cohen and Dupas 2010, Kremer et al. 2011, Dupas 2014), credit constraints (Tarozzi et al. 2014), time preferences (Tarozzi et al. 2009) , lack of information and awareness (Dupas 2009, 2011a) and peer effects (Kremer and Miguel, 2007; Oster and Thornton, 2012) are among the most important barriers to health technology adoption.
In many cases, modern cookstoves benefit users of fuel saving, due to their higher efficiency compared to traditional cooking methods. Several works have tried to analyze the diffusion of energy efficient practices both in developed and developing countries.

Some recent works have tried to investigate the role of the barriers which prevent adoption, daily use and maintenance of improved cookstoves, through regression analysis of the drivers of demand. The main drivers associated with improved cookstoves adoption are related to socio-economic status: income and education are positively associated, whereas socially marginalized status is negatively related to purchase and use. Price of firewood also seems to be a key factor (Lewis et al. 2012, Alem et al. 2013, Pozzuolo et al. 2013). However, most of such studies do not address the issue of causal inference, through the identification of proper counterfactuals and are therefore limited to the indication of correlations and relevant associations. Very few studies rigorously assess the role of barriers to adoption in the domain of improved cookstoves. Among them, several confirm the crucial role played by prices and liquidity constraints on the decisions to buy, use and maintain improved cookstoves (Hanna et al. 2012, Miller and Mobarak 2013a, 2013b), even though after relatively high subsidies uptake decisions remain relatively low (Mobarak et al. 2013). Miller and Mobarak (2013a) find that propensity to adopt modern cookstoves differs for women and men: women have a stronger preference towards the new technology but lack sufficient authority and bargaining power within the household to impose their decision on men. In another paper, Miller and Mobarak (2013b) highlight the important role of opinion leaders and social networks in conveying information on the attributes of the new technology and decisions to adopt. Levine et al. (2013) propose an offer combining free trial period, significant increase in the purchase of the product, compared to a traditional cash-and-carry offer.

Learning the drivers of adoption, diffusion and continuous use is of great relevance in order to strengthen evidence-based actions and policies. Further research should focus on the roles of household level decision making, gender, cultural traits, liquidity and credit constraints, but also behavioural factors, local institutions and social networks (Foell et al. 2011).

Table 5. Barriers to the adoption of electrification and improved cookstoves

	Main results	Study, geographical region	Method	Sample size (level)	Period (n. of time obs)
Electrification					
Liquidy constraints	Reductions of 20% of fixed connection cost lead to 13% increase in connection	Bernard and Torero (2014), Ethiopia	RCT	563 (household)	(2)
Social networks	Evidence of bandwagon effects in the decision of connecting to the grid in rurla areas: having more people conncected in the nneighbourhood increases the individual propensity to be connected	Bernard and Torero (2014), Ethiopia	RCT	563 (household)	(2)
Cookstoves					
Prices, Adoption rate, use and maintenance	60% adoption rate with a 94% subsidy. Only 3 extra meals on the improve per weeks than control. 36% more hh maintained the improved cookstove	Hanna Duflo and Greenstone (2012); India	RCT	2651 (household)	2005-2010 (2)
	97% orders and 69,5% purchase for free stove; 70% order and 27.5% for subsidized at 80% average subsidy	Miller and Mobarak (2013a); Bangladesh	RCT	800 (household)	2008 (1)
	25% orders and 3% actual purchase at full price; 40% order and 11% purchase at half price	Miller and Mobarak (2013b); Bangladesh	RCT	2100 (household)	2008-2009 (2)
	50% discount implies an increase of 25% in intentions to buy . Elasticity of demand to price is higher for poorer hhs. Small actual purchase at full price (2-5%), 5-12% increase in purchase after 50% discount. Strong role of liquidity constraints	Mobarak et al. (2012); Bangladesh	RCT	2280 (household)	2008 (1)

Marketing	4% uptake with traditional cash and carry offer and 46% uptake with a novel offer with free trial and time payments. Individually time payments generates 22% uptake and right to return 33%. Cookstoves were offered at full price (6-10$)	Levine, Beltramo, Blalock and Cotterman (2013, WP)	RCT	1690 (household)	2010 (1)
Intra-household decision making	When offered for free, after education on health benefits, both men and women prefer the health-imporving (with chimney) stove. Women prefer it more than men. When small prices are charged, no difference between men and women	Miller and Mobarak (2013a); Bangladesh	RCT	800 (household)	2008 (1)
Opinion leaders	Positive (negative) effect of unanimous acceptance (rejection) of purchase by opinion leaders on efficiency stove orders. No positive effect on chimney stove, only significant negative effect from unanimous rejection. Info from opinion leaders is more salient at lower prices. No effect of opinion leader on actual purchase. Only unanimous rejection significantly decreases actual purchase	Miller and Mobarak (2013b); Bangladesh	RCT	2100 (household)	2008-2009 (2)
Social networks	Negative effect of social network on purchase: more network members purchased in first round, less likelihood of buying in the second round for members of the same network: overly optimistic opinions about benefits of cookstoves	Miller and Mobarak (2013b); Bangladesh	RCT	2100 (household)	2008-2009 (2)

4. Universal access to modern energy services: macro impacts on sustainability

At a more macro level, assessing the impacts of universal programs of electrification and of access to clean fuels and improved cooking methods means looking at the global consequences in terms of demand of energy, necessary investments and climate change, under different scenarios.

At global level, pathways to achieve universal access to energy at global level should combine dedicated policies enabling affordability of modern cooking fuels and stoves and rapid rural electrification. It is estimated that this could be possible with additional investments in the range of 3 to 4% of current investments in the global energy system (Pachauri et al. 2013).

The consequences of eradicating energy poverty in terms of global demand of energy and environmental impacts are still debated. The IEA estimates that universal access by 2030 would increase electricity by 2.5%, and fossil fuels by 0.8%. In other studies, it is argued that specific pro-poor policies may lead to higher increase in energy demand beyond expectations (Gertler et al., 2011; Wolfram et al., 2012). Chakravarty and Tavoni (2013) find that providing enough energy to assure basic human needs satisfaction and some productive uses (10GJ per capita per year) would imply a 7% increase in global energy demand, with very uneven geographical distribution (e.g. +107% in Sub-Saharan Africa). Climate impacts of universal access to energy are estimated to be relatively limited: according to different studies the World Bank (World Development Report 2010) it would lead to 0.6 to 2% increase in CO_2 emissions[9] and negligible rise in global temperature, i.e. less than 0.1°C (Chakravarty and Tavoni, 2013).

[9]The estimates refer to IEA (2012, based on the New Policy Scenario) and World Bank (2010)

5. Conclusion

Large global imbalances and inequities in access to energy have recently stimulated an important policy debate which is likely to influence the post-2015 development agenda. Access to electricity, particularly in rural areas, and the introduction of improved cooking technologies, beyond the use of wood and biomass, are crucial development challenges for their close link and implication for household health, education, welfare, labour market and business. Although a great effort in the last decades has been done to monitor progress and report initiatives, rigorous impact evaluation studies of programs (at all scales) are rare. This paper reviews the most recent literature on the impact evaluation of access to electrification and adoption of improved cookstoves on several relevant outcomes, based on solid identification strategies and estimation techniques.

Table 6: summary of results

	Average effect	Uncertainty
Access to electricity		
Labour market	+	Medium
Welfare and health	++	Low
Business	+	High
Improved Cookstoves		
Health	-	High
Welfare	(+)	High

As highlighted in Table 6, the literature seems to suggests that access to electricity is a strong causal determinant of changes in labour market outcomes: employment and revenues rises in connected areas. Interestingly, such changes concern women and activities not related to agriculture. Access to electricity also seems to have strong impacts on schooling and household welfare. Conversely, the literature is still very divided as to the impacts of the adoption of improved cookstoves on health and household welfare outcomes. More research is needed to enrich the debate, possibly coming from different contexts and products, given the high variability in technologies across the world.

Understanding the impact of access to modern energy services on household welfare, labour market outcomes and gender empowerment and the best ways to help decision-makers to implement effective policies and interventions are of key relevance for development in society. Evidence-based considerations on efficacy and efficiency of modern energy adoption-enhancing strategies are extremely important when resources to cooperation and development are scarce.

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