Poverty, Inequality and the Decarbonization of Economic Development

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Introduction

1.1 Anthropogenic climate change and developing countries

The influence of human activity on the climate is increasingly considered as secured knowledge in the academic community. Driven by economic and population growth, anthropogenic greenhouse gas emissions (GHG) have increased since the pre-industrial era and "led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years" (IPCC, 2013). Anthropogenic drivers are, according to a large majority in the scientific community, extremely likely to have been the dominant cause of the observed warming since the mid-20th century. If mankind continues to emit GHG emissions at current magnitudes, major changes in the climate system can be expected to occur. Despite a considerable uncertainty, contemporary model predictions show high chances for severe consequences in all regions of the world (IPCC, 2013).

Developing countries are particularly threatened by negative consequences of global warming and they are increasingly contributing to man-made climate change through their growing share in global GHG emissions (Olivier et al., 2015).[1] They are thus confronted with a two-fold challenge: on the one hand, effects of climate change can potentially threaten the existence of some countries via higher temperatures, changed precipitation patterns, higher sea levels, and more-likely extreme weather events (IPCC, 2014). For the majority of humans living in developing countries, this will likely be a major challenge for improving livelihoods. On the other hand, effective climate change mitigation options are in conflict with developing countries' legitimate development goals. With economic growth being a major explanatory

[1] The term "developing countries" is used as a broad categorization for "low- and middle countries" as defined by the World Bank. Both terms are used interchangeably in the text.

variable for both GHG emissions and poverty alleviation, developing countries face a difficult but critical trade-off with consequences for their inhabitants' livelihoods and global climate change trajectories. With this thesis I seek to contribute to the understanding of this dual challenge by analyzing the relationship of poverty, inequality and greenhouse gas emissions on the household level in three countries, India, Mexico and Indonesia. By adopting a micro perspective, my work tries to add a much needed viewpoint for the question of how households in developing countries will be affected by climate mitigation policies, and how they are able to contribute to global GHG emission reduction efforts.

Strong mitigation commitments by developing countries are indispensable despite the historical debt of developed countries. Although rather political than scientific, the consensus emerged that negative consequences from climate change could be manageable if the global mean surface temperature rise remained below 2 degrees Celsius (Knutti et al., 2016). Despite the scientific uncertainty, reaching the 2-degree target or similar goals requires significant reductions of global GHG emissions. How much each country should reduce its emission level has always been and continues to be a major dispute at the international policy level. A major conflict line lies between developed and developing countries and culminates in the question of accounting principles for determining each country's reduction responsibilities. Depending on the point of view, which often relates to the perspective of developed or developing countries, emissions should either be calculated at the production or consumption level, with further refinements in per capita and historical time dimensions. Current production emission levels in the world are dominated by low- and particularly middle-income countries. Together, they account for two thirds of annual global emissions with a rising trend (Olivier et al., 2015). Although today's developed countries have a declining share in total global GHG emissions, their historical responsibility is still large. Considering cumulated emissions since 1850, the developed countries' share is at 50 percent, although with a declining trend and predicted to fall to 45 percent by 2020 (Elzen et al., 2013; WRI, 2014). However, the use of production emissions is problematic. A large share of goods produced in developing countries is exported to developed countries. In fact, a non-marginal share of emission stabilization in high income countries can be explained by production and thus emission outsourcing to developing countries (Peters et al., 2011).[2]

Due to these antagonistic approaches to accounting for national GHG emissions and consequently differing understandings of responsibility (Cole, 2015; Ostrom, 2010), international climate negotiations have been in a deadlock for years. On the one hand, historical emission paths suggest a clear policy implication that developed countries have to reduce

[2]The production perspective provides already enough evidence against an Environmental Kuznets Curve for GHG emissions (Sanchez and Stern, 2016; Stern, 2004). A demand side accounting approach adds more evidence against it.

GHG emissions drastically and immediately if extreme climate effects are to be avoided (Althor et al., 2016). On the other hand, reducing global GHG emissions to a level, which allows staying within the 2 degrees Celsius target, is simply not achievable anymore without developing countries' mitigation commitments (IEA, 2011). The situation is exacerbated since there is growing evidence that the world is already locked-in on a 1.5 degree increase until the middle of the century (World Bank, 2014). The current speed of emission growth from simulation studies suggest that the world is likely on a path towards a 4 degree warming scenario and that recent increases in developing countries emissions puts considerably more pressure on emission reduction efforts.

The Paris agreement represents a major advancement compared to prior efforts at the international policy level, but developing countries' legitimate development aspirations are still capable of threatening effective emissions reductions. Whether or not current scientific predictions have any direct impact on national policy making remains to be seen. However, major movement occurred recently on the international climate policy stage. 191 United Nations Framework Convention on Climate Change (UNFCCC) member countries signed the first-ever universal and legally binding global climate treaty at the Paris climate conference (COP21) in December 2015. Unlike the Kyoto protocol of 1997, almost all countries are expected to set mitigation goals including the large low- and middle-income countries. The Intended Nationally Determined Contributions (INDC) are unilaterally determined and supposed to reflect each country's ability to contribute to mitigation efforts.

A look into published INDCs of developing countries reveals three major issues, which make the assessment of emission reductions and its economic implications difficult. First, emission reduction goals are usually stated relative to a baseline scenario, which are easily manipulated to claim larger projected emission reductions. Second, mitigation goals are typically formulated along two different scenarios. Unilateral goals are less ambitious than goals that can be achieved by drawing on bilateral or multilateral assistance. Since the size of multilateral transfers is uncertain today, there is also considerable uncertainty regarding future emission savings. Third, INDCs hardly contain specific policy details and further steps for achieving emission reductions. A general trend observable in developing countries' INDCs is the strong emphasis on development goals. Behind this reasonable interest is an inconvenient truth that will be decisive for successful climate stabilization. The ratified Paris agreement will only be implemented starting 2020, at a time when a large fraction of energy infrastructure will already be locked into fossil fuels (IEA, 2014). Investments in replacing this infrastructure are costly, and unlikely to be made when they threaten the development agenda of a poor country. Therefore, a closer look at and thorough analysis of trade-offs is an important issue for understanding the political feasibility of ambitious mitigation policies.

1.2 Mitigation and development: discussions of trade-offs and synergies

Economic growth has shown to be a necessary condition for reaching development goals and the improvement of living conditions of the poor. The worldwide poverty headcount ratio at the $ 1.9/day poverty line decreased from 44 percent in 1981 to 12.7 percent in 2012 (World Bank, 2016). A large share of the population, which has escaped extreme poverty, can be found in India and particularly China, but plenty of other countries all over the world, such as Indonesia, the Philippines, Mexico, Pakistan, Uganda, or Ghana among them, have experienced substantial reductions in extreme poverty as well. The assertion of economic growth being the single most important driver behind this reduction in income poverty is well supported. On a cross-country level Dollar and Kraay (2002) show a proportionate relationship between average income growth and the income of the poorest 20 percent of the population. Revisiting the question Dollar et al. (2016) find that about 75 percent of income growth for the poorest 40 percent of the population is explained by average income growth. At the country level there is also overwhelming evidence of the strong effect of growth on poverty reduction. Ravallion and Datt (1996) report a strongly negative elasticity of poverty incidence with respect to mean household consumption for India. Certainly, there are also examples demonstrating that growth is not the only important factor for poverty reduction, as recently described for India by Dreze and Sen (2013). Finally, a consensus in the literature appears to be that economic growth is a necessary but not sufficient condition for an improvement in living conditions of the poor. In any case, without sustained economic growth in low- and middle-income countries, a complete eradication of poverty will be doomed to failure.

The economic growth needed for the achievement of development goals is tightly associated with increased energy use and respective GHG emissions, creating a dilemma which amounts to one of the biggest challenges in the history of humankind. No country has ever managed to reach a high level of economic development without crossing an energy threshold of about 40 GJ per capita (Steckel et al., 2013; Steinberger and Roberts, 2010). Without a widely-available modern energy infrastructure supply and large energy inputs in production, development goals are impossible to achieve. Current price differentials of fossil fuels versus renewable energy clearly favor the former, although renewables have recently become more competitive (IRENA, 2015). To avoid risking long-term lock-ins into the fossil energy supply, the discussion is ongoing how low- and middle-income countries can achieve economic growth with a low carbon intensity at an earlier stage of development compared to high income countries which started this process only recently. One frequently debated strategy trying to overcome this dilemma is "greening the economy," which is broadly defined as structural rearrangement of economic and especially energy conversion processes by large-scale applications of low carbon technology while maintaining productivity and competitiveness at the same time.

Conceptual reports on greening the economy by international institutions such as the World Bank, OECD or UNEP draw an overall optimistic picture while theoretical and empirical backing of the concept's capability to solve the dilemma is still lacking. UNEP (2011) takes the strongest stance on the synergies of economic growth and environmental policies, stating that "greening the economy can generate consistent and positive outcomes for increased wealth, growth in economic output, decent employment and reduced poverty". The arguments for strong green growth synergies are debatable for two reasons, as they imply that non-converters to a green economy might miss out on potential extra achievements in their development agendas. First, there is neither a theoretical argument nor empirical evidence available in support of seeing natural capital stock reduction as a major slow down factor for conventionally measured GDP in the short to medium run (Schmalensee, 2012). In the case of climate change and fossil fuels, there is no indication for fossil fuel usage slowing down economic growth and poverty reduction in the near future. According to the latest information on the fossil fuel resource availability (Shafiee and Topal, 2009), in the next decades there is neither an expected resource shortage inducing growth decline, nor an expected self-regulation of energy prices, which could make renewables more competitive. Second, simulation studies of mitigation policies usually conclude that strong emission reduction goals, contrary to synergistic arguments, reduce GDP compared to the business as usual scenario (Carraro et al., 2012; Edmonds et al., 2012). When the cost of transforming energy from fossil fuels is cheaper compared to renewable energy sources, production costs rise. It can also be ruled out that the general growth effects from these studies cannot be applied to developing countries as well. The extra costs generated by the more expensive fossil fuel substitutions will consequently be at some party's expense, which in turn is the simple reason for most countries' cemented reliance on fossil fuels.

However, strategies for internalizing externalities, e.g. by taxation of carbon emissions, possibly help leverage synergy potentials of development goals and GHG emission reductions. Adding to the environmental benefits of reduced GHG emissions in the atmosphere, taxation of GHG emissions might provide a so called second dividend. A reduction of other distortionary taxes may result in an efficiency gain and improved total welfare. The literature on the so called "double dividend" often focuses on employment gains through a reduction in labor taxes (Bovenberg, 1999; Goulder, 1995) but also capital tax reductions are shown to lead to aggregate welfare gains (Jorgenson et al., 2013). There are also arguments in favor of “triple dividends”, although the definitions here differ widely: Garbaccio et al. (2000) find additional health benefits through a reduction of air pollution, which was termed the “third dividend” by Dale Jorgenson (Shaw, 2014). Heerden et al. (2006) define their “third dividend” as a reduction in poverty, which appears not to be fundamentally different from the second dividend after all. Again another definition is used by Pereira et al. (2016) who speak of lowering public indebtedness as the third dividend. All these potential efficiency gains are important factors to consider for a concluding judgement about the overall growth effect of mitigation policies. Due to the small number of implemented mitigation policies in real world contexts, and the complexity of modelling these effects ex-ante, the literature has little to offer on these points for developing countries.

Despite some well-founded arguments in favor of possible synergies between climate mitigation policies and economic development, there are still major obstacles to be overcome in the short-run. The OECD, although advocating green and low carbon growth, is cautious by considering potential problems such as distributional impacts in the transformation process (OECD, 2011). In a recent stock-taking of the green growth agenda, it is emphasized that a better understanding of opportunities and trade-offs of green growth policies is crucial for any realistic change in their implementation (OECD, 2015). The World Bank has also become very active recently in the green growth debate. Hallegatte et al. (2011) provides a very general discussion of possible green growth scenarios. Adding the term “inclusive” in a subsequent report, green growth is described as “necessary, efficient and affordable” (World Bank, 2012, p. 3). Although sharing an optimistic tone, most advocates of low carbon growth can certainly not be blamed for a careless handling of possible trade-offs with development goals. Striking however is the relatively large abstraction of the discussion and a major lack of specific policy guidance, particularly for low carbon development in low- and middle-income countries. A skeptical and more focused perspective on low carbon development is shared by Jakob et al. (2014), who recommend a modest approach in identifying mitigation actions with clear benefits for developing countries. They identify feasible policy options, such as the reduction of fossil energy subsidies and decentralized renewable energy for rural areas. However, these policies’ suggestions partly miss to answer the urgent question of how large emission reductions can be realized in the short-run. Other economists are also generally skeptical of synergistic green economy programs and point to the short-run costs in developing countries as a major obstacle in implementing low carbon policies (Bowen and Hepburn, 2014; Dercon, 2014).

Exploiting mitigation cost differentials on the global level as another possible way to overcome the mitigation-development dilemma is seemingly also not living up to its promise. In line with the size of GHG emissions, the largest mitigation potential lies in non-OECD countries (Akimoto et al., 2010; van Vuuren et al., 2009). Developed countries thus could contribute to mitigation and development by financing the installation of renewable energy capacity in developing countries. Large cost differentials can often be found in studies based on Marginal Abatement Costs (MAC) Curves. This approach is widely and often advocated by the private consulting firm McKinsey (Nauclér and Enkvist, 2009). Academic economists have criticized these cost assessments on various grounds (Kesicki and Ekins, 2012): among many methodological issues, the allurement of negative abatement costs, which are hailed as cost-free low hanging fruits, are an elusive promise and proof of their existence still needs to be delivered. The Clean Development Mechanism (CDM), part of the Kyoto protocol and most prominent example for this approach, has not lived up to its expectation either and a succeeding mechanism is not in sight. Large capital transfers to developing countries for boosting renewable energies are also potentially problematic. Based on historical experience with development aid, large capital transfers may come with a "climate finance curse" (Jakob et al., 2015) analog to the effects described in the resource curse literature (van der Ploeg, 2011). In total, the mitigation-development dilemma does not seem to be easily resolved into a synergistic win-win situation, leaving developing countries with an unclear perspective regarding potential outcomes of climate policies.

1.3 Distributional effects: decisive for the feasibility of climate policy

The unclear impacts of climate policies on household incomes and especially the distribution of these impacts are particularly problematic. They depend on a variety of often under-researched factors. However, the elucidation of these factors is important regardless of their existence and implementation problems in international carbon finance projects. For low carbon development strategies, developing countries will likely be dependent upon international assistance to some extent. However, multilateral assistance will not be able to fundamentally change the incentive structure and determine how much renewable energy is used over the next decades. National policies are needed to supplement climate finance in setting the incentives towards low carbon energy sources. However, as a critical review of the catchy green or low carbon growth slogans show, many problems await for those countries, which are planning to go down the road of climate policies. Much of the political discussion on low carbon development focuses on abstract discussions with limited substantial analytical value and policy guidance. This is surprising, considering that the economic literature can deliver analytical tools to access complicated topics, such as the incidence of market-based environmental policies. These instruments, putting a price on GHG emissions either in the form of taxes or emission permits, will have to play a major role in any ambitious decarbonization process. Like any other policy, putting a price on carbon will produce winners and losers. The identification of these groups and quantifying the impacts are a highly needed deliverable by the scientific community that this work tries to contribute to.

Fullerton (2008, 2011) discusses six distributional effects, which are worth looking at in more detail and guide the way for the subsequent chapters in this work. Market based climate mitigation policies try to correct for the environmental externalities created by the polluting fossil fuels. The public economics literature has much to say on the general distributional effects of taxes, but environmental policies are in fact more complicated and interesting as Fullerton (2011) points out. The reasons behind this are that environmental policies are not exclusively taxes but also include quantity regulations, such as emission trading schemes or command and control policies. Specifically, the different effects are (1) higher prices of carbon intensive products, (2) changes in relative returns to factors like labor, capital, and resources, (3) allocation of scarcity rents from a restricted number of permits, (4) distribution of the benefits from improvements in environmental quality, (5) temporary effects during the transition, and (6) capitalization of all those effects into the prices of land, corporate stock, or house values. With the exception of effect (3), which only holds for an emission trading scheme, all of these effects are also present in the cases of carbon or energy taxes. Under particular circumstances, all these single effects can be regressive (a higher burden as a fraction of income for the poor compared to the rich) or progressive and the overall effect is a priori unknown. A discussion of these effects and the available evidence in detail is helpful in understanding their importance and the current state of research.

First, prices of fossil fuel-intensive products are likely to rise, which will affect the consumption costs of households, the so called “uses” side. In developed countries, the uses side is found to be dominantly regressive since poor households spend relatively more on high carbon intensive goods, such as electricity and fuels (Grainger and Kolstad, 2010; Mathur and Morris, 2014). How regressive the impact is depends on whether welfare effects are calculated relative to household income or expenditures, the latter usually claimed to better represent lifetime income measures. Expenditure based assessments are found to be less regressive than effects relative to income (Bull et al., 1994; Dinan and Rogers, 2002; Metcalf, 1999). Shah and Larsen (1992) have warned early of applying the standard regressivity result unquestioned to developing countries, as direct use of modern energy can be lower for poor households. In urban areas the electricity grid connectivity is higher, which correlates positively with income. Private motorized transport expenditures are closely tied to the ownership of motorized transport vehicles, again positively correlated with income. Also modern fuels for cooking, such as gas, are unlikely to be used more by the poor who often depend on traditional biomass fuels such as wood and dung for cooking. The uses side incidence of energy and carbon taxes may therefore be progressive in developing countries. Finally, the extent to which higher prices are passed through to consumers will depend on the shape of their demand curve. Since energy markets are usually dominated by international market forces and national regulation, it is very likely that energy price increases are entirely passed through to consumers. The substitution between fuels is then ultimately deciding on the monetary burden from taxation.

Second, depending on how factor demand changes through the price increase, the income of workers or capital owners will be affected through the "sources" side. If energy or fossil fuel intensive goods can best be replaced by new capital intensive technologies, relative wages will fall, returns to capital rise and the policy will be regressive. On the other hand, a carbon tax may be more burdensome to capital-intensive industries and disproportionately reduce the return to capital. If so, and if capital provides a higher share of income for richer households, then the sources side incidence may be progressive. In particular, the effect on the sources side depends on the elasticities of substitution in production for polluting industries, elasticities in labor supply and demand, and capital market conditions. There is very little empirical literature on this question, which forces modelers of simulation studies to use "plausible values". The results in this branch of literature are naturally mixed. Fullerton and Heutel (2007) describe the effects of carbon taxation on the different factor prices and conclude they depend critically on the substitutability of capital, labor, and emissions. In a follow-up paper, Fullerton and Heutel (2011) show that the incidence of a carbon tax on the uses side is regressive, the incidence on the sources side can be progressive, U-shaped, or regressive, depending on the parameters. Rausch et al. (2010) find that under certain circumstances, the progressive impacts of a carbon tax on the sources side exceed the regressive impacts on the uses side, which in sum leads to a mildly progressive effect even without recycling of the revenues. Fullerton and Monti (2013) show that even when accounting for potential progressivity on the uses side, the burden a carbon tax places on the lowest income cohort can never be offset completely. Concluding, results on the sources side are sensitive to parameter values in numerical simulation models and remain an unresolved subject of empirical research. For labor abundant developing countries, the chances of progressive effects through capital intensive renewable energy installments are relatively low as put forward for Africa by Collier and Venables (2012).

If the climate policy is a quantity based instrument, there will be a third effect consisting of scarcity rents following the hand out of pollution permits which will benefit the individuals who own those firms. In the first phase of the European Emission Trading Scheme (EU ETS), almost all emission permits have been grandfathered to companies. Since emission permits are afterwards traded and therefore worth the resulting market price, consumers face rising energy prices while financing the permits with their taxes (Dinan and Rogers, 2002; Parry, 2003). The only immediate beneficiaries are the stockholders of the polluting companies, which are unlikely to sit at the bottom of the income distribution. Plain and simple, giving permits away for free is a way of combining environmental policy with redistribution from the bottom to the top.

Fourth, climate policies have the ultimate goal to reduce greenhouse gas emissions, and the associated environmental improvements may lead to a heterogeneous effect in the population. Air quality improvements through less fossil fuel intensive electricity generation, road transport, and industry production is likely to affect the urban more than the rural population. In this case, the distributional impact depends on the spatial distribution of income in polluted and less polluted areas. Although this intra-country distribution hasn't been analyzed in the literature thus far, in a cross country comparison Markandya et al. (2009) report large health benefits of low carbon electricity generation in poor countries like India. Agricultural productivity, which is already lower in less temperate regions of the world, would further decrease in poor countries with climate change. Developing countries with large agricultural shares in their gross domestic product would benefit more from climate mitigation efforts than developed countries in temperate world regions. Dell et al. (2009) come to the conclusion that higher temperatures reduced income growth in poor but not in developed countries. Beyond an increase in temperatures, the possible increase in extreme events and natural disasters may also hurt the poor more than the rich. In this case, the difference may not be entirely explained by agricultural activities, also non-agricultural growth is affected (Fomby et al., 2013; Raddatz, 2009). The benefits of climate mitigation would therefore likely be progressive, also within these countries.

Fifth, the transition towards a low carbon economy may have very different effects on poor and rich households. With imperfect mobility of production factors, returns to capital or wages are not the only effects on the sources side. Additionally, large disruptive changes in employment and capital degradation might occur. Deschenes (2010) analyzes the effects of electricity prices on labor demand for the US and finds a low, but negative cross-price elasticity. As with other effects, the time horizon used for the analysis is critical. Short-term effects as calculated by Deschenes (2010) ignore a firm's innovation responses to higher energy prices (Popp, 2002; Popp et al., 2009), which may change the story dynamically over time; but literature for developing countries is neither available for static nor for dynamic effects. The other side of the coin, the creation of "green jobs" is often hailed as the ultimate win-win case of climate policy and green growth. There is little empirical evidence of this phenomenon, but existing studies shed serious doubt on the existence of a green job miracle, in particular for developing countries. In the case of climate policies, green jobs are mostly defined as jobs in the renewable energy industry. For developing countries, Dercon (2014) argues that the low-skilled-labor intensity of these industries will finally decide if the poor benefit from this development. Wei et al. (2010) argue that the renewable energy sector is more labor intensive and therefore creates more jobs than the fossil fuel using energy sector. This, however, appears to be a rather optimistic assessment since energy prices are also higher for renewables, use more inputs per energy unit, and it is not clear what the net employment effect finally is (Fankhauser et al., 2008). For industrialized countries with large scale support of renewable energies such as Germany, there are contradicting findings that the net job creation is either positive (Lehr et al., 2012) or negative (Frondel et al., 2010). In any case, it appears that the export of technologies is essential to achieve a potentially positive net employment effect. Currently, the large majority of renewable energy technologies are developed in rich countries and this is unlikely to change in the short- to medium-run. Therefore, a low carbon job miracle is unlikely to be a plausible scenario for poverty reduction and progressive distributional effects.

Sixth, all those effects are capitalized into the prices of assets. If climate policy affects the expected future returns from houses, land, or corporate stock, the owners or renters of these assets will be differently affected. For developing countries, important factors are e.g. the ownership of agricultural land or the geographical vulnerability of asset ownership to sea level rises. Apart from cross-country evidence reporting a high vulnerability of developing countries (Dasgupta et al., 2008; Mendelsohn et al., 2006), intra-country evidence is missing.

Eventually, in the case of raised revenue through taxes or permits, the reallocation of these revenues to households may change the net effect of all impact channels described above. Many studies find that redistribution can make any carbon tax reform progressive, although as Rausch et al. (2011) note, this may come at the cost of efficiency.

1.4 Contribution to the literature

Considering the various distributional effects that potentially result from climate policies, data limitations and methodological challenges do not allow me to investigate them empirically in one piece of analysis. This holds particularly for developing countries, where necessary data is even harder to come by. Despite the apparent difficulties to deliver analytical studies incorporating the variety of potential welfare effects, the immediate need for knowledge in this field demands urgent action in research. For developing countries there is some literature available for impacts on the uses side and some Computable General Equilibrium (CGE) studies including effects on the sources side.

The uses side literature is predominantly based on descriptive patterns of household energy expenditures as in Sterner (2011), with critical and untested assumptions of completely inelastic energy demand. This simplified approach has two important drawbacks: First, welfare effects are mismeasured when households deviate from the assumption of inelastic demand. Second, inelastic demand implies zero impact on the emission of GHGs. CGE studies on the other hand, dealing also with sources side effects, include demand elasticities. These models come with different problems however. Demand curves are often of a simplified linear form and of dubious empirical credibility as are other used functional forms and parameters. Additionally, energy expenditures are difficult to disaggregate on a single fuel level which misses much of the substitution between different fuels. Usually, the emission accounting is also production based, which ignores the actual effect from emissions contained in consumption goods. Last but not least, welfare assessments based on average households always miss out on heterogeneity between households, which can be critical in distributional assessments.

In this thesis I try to address all of these problems in a unified, theoretically consistent and empirically tested model structure. Thereby I focus on household expenditures and the uses-side effects in order to deliver short-run but reliable analyses of household welfare impacts resulting from energy and climate policies. The consumption perspective is also strictly maintained in assessing the GHG emission implications. As a novelty in the literature of energy and climate policies in developing countries, I introduce an emission accounting framework for households based on actual emitted GHG in consumption.

In all chapters I employ partial equilibrium models with a maximum of detail in terms of household heterogeneity and energy demand. Additional to purely descriptive components of household consumption patterns, these models incorporate estimated household demand responses to policy interventions. These detailed partial equilibrium models are not substitutes for more general CGE models but complements, which help to go beyond average effects and offer as much heterogeneity as possible. The disadvantages are naturally the lack of indirect effects through factor markets, the missing total, general equilibrium effects, and the strong short-term focus of the analysis. At least for policy guidance, the latter does not appear to be extremely harmful. The estimated and simulated effects are all effective immediately after the policy implementation, which facilitates the practical understanding of results. In general, the used household demand model, the Quadratic Almost Ideal Demand System (QUAIDS), is of neoclassical nature and can also be used as a demand module in a CGE model, which would reconcile this line of work with studies incorporating different impact channels such as sources-side effects at the same time.

To lay the ground for the emission accounting from the demand side, the second chapter describes the calculation and analysis of household carbon footprints for Indian households. Estimates of household CO_2 emissions caused by the direct use of energy or indirectly through the consumption of other goods are rare for developing countries. Addressing this research gap I apply an environmentally extended input-output analysis matched with Indian household expenditure data to estimate the carbon footprint for Indian households in the years 2004/05 and 2011/12. I analyze the consumption dynamics behind the growing carbon footprints in a structural demand model framework. Between the two surveys, CO_2 emissions contained in household consumption grew slightly faster than consumption itself. The scale effect of higher consumption is therefore ruled out to be the only factor for emission growth from Indian consumers. By estimating the income elasticities of major groups of consumption items, I am able to investigate the effect of changes in household consumption patterns to identify the composition effect. Although the scale effect dominates, high income elasticities for carbon intensive consumption items are likely to accelerate future growth in household carbon footprints. Electricity and private transport are mainly responsible for this slightly nonlinear emission growth effect.

In the remaining chapters, I put the focus on distributional effects of climate mitigation policies. The third chapter starts out with a closer look at welfare effects of carbon taxes in Mexico. Mexico recently declared ambitious goals in reducing domestic CO_2 emissions and introduced a carbon tax in 2014. Although negative effects on household welfare and related poverty measures are widely discussed as possible consequences, empirical evidence is missing. I try to fill this gap by simulating an input-output model coupled with household survey data to examine the welfare effects of different carbon tax rates over the income distribution. The currently effective tax rate is small and has negligible effects on household welfare. Higher simulated tax rates, maintaining the current tax base, show a slight progressivity but welfare losses remain moderate. Welfare losses, regressivity and poverty rise more with widening the tax base towards natural gas and other greenhouse gases (CH_4, N_2O) through food price increases. For a complete analysis of the policy, I simulate a redistribution of calculated tax revenues and find that the resulting effects become highly progressive, also for high rates, wider tax bases and even in the absence of perfect targeting of social welfare programs.

Chapter 4 builds on chapter 3 but deals with the weaknesses of the modelling framework, which is incapable of estimating household responses to policy induced price changes. Therefore, I analyze not only the effects of environmental taxes on household welfare but also on carbon emissions at the household level for the case of Mexico. The integrated welfare-environmental analysis that is based on a censored energy consumer demand system extends previous work in two ways. First, the estimation of a full matrix of substitution elasticities allows testing the necessity of incorporating second-order effects into the welfare analysis. Second, the derived substitution elasticities from the demand system are used to estimate the short-run CO_2 emission reduction potential. For the Mexican case, I find first-order approximations of welfare effects to provide reasonable estimates, in particular, for carbon taxes. Analog to evidence in other low- and middle-income countries, the taxation of all energy items is found to be regressive with the exception of motor fuels. The inclusion of CH_4 and N_2O in a carbon tax regime comes along with particularly regressive impacts because of its strong effects on food prices. The analysis of the emission implications of different tax scenarios indicates that the short-run emission reductions at the household level can be substantial – albeit the effects depend on how revenue is recycled. This effectiveness combined with moderate and manageable adverse distributional impacts renders the carbon tax a preferred mitigation instrument. Considering the large effect of food price increases on poverty and the limited additional emission saving potential, the inclusion of CH_4 and N_2O in a carbon tax regime is not advisable.

In the final chapter, using extended methodology from the other chapters in one piece of analysis, I put the spotlight on energy subsidies in Indonesia. Consumer energy prices in Indonesia have been regulated by the government for a long time with a recent change in subsidy policies, facilitated by dramatically falling oil prices. I study welfare, energy poverty, and CO_2 emissions implications of energy price change scenarios. The analysis extends previous work of energy price and subsidy removal impacts at the household-level in several ways. First, by employing a household energy demand system (QUAIDS) the analysis shows considerable heterogeneity of welfare impacts. For gasoline and electricity, first-order calculations are overestimating welfare effects by 10-20 percent with price changes between 20 and 50 percent. This holds particularly for gasoline and for richer households, which have higher usage rates. Second, the results point at another source of impact heterogeneity due to the ownership of energy-processing durables. Poor households that own these goods may be hit particularly strong by energy price rises. Third, I extend the welfare analysis beyond the money metric utility effects and look at energy poverty understood as a condition of missing or imperfect access to reliable and clean modern energy services. By drawing on the estimated demand function and resulting price elasticities, I find substantial effects of price increases on energy poverty. Fourth, the analysis explicitly considers the emission effects of the energy price scenarios. Albeit these effects are estimated with some uncertainty it turns out that reduced household energy demand implies a substantial reduction in emissions. The analysis thus indicates that energy taxes may serve as an effective mitigation instrument, but are accompanied with important adverse welfare effects that can, however, be cushioned by appropriate compensation policies.

Chapter 2

The carbon footprint of Indian households

2.1 Introduction

Household income in India has increased considerably in line with economic growth over the last decades with a clear acceleration since the early 1990s. Although aggregate economic growth rates of India may have not transformed into a magnitude of poverty reductions that was hoped for (Dreze and Sen, 2013), substantial reductions in the poverty rate of 35 percentage points have been achieved since the end of the 1950s until 2012 (Datt et al., 2016).[1] With sustained economic growth and an increasing share of the population leaving extreme poverty, consumption and associated energy use are expected to grow rapidly as well. As positive as this development process is, energy used in the production of goods and energy used directly by households comes to a large extent from fossil sources (IEA, 2015). Current CO_2 emission levels per capita are low in international comparison but the large population size of India makes the country the 3rd biggest total CO_2 emitter in 2014 behind China and the USA (Olivier et al., 2015). India's growth rates in energy use and CO_2 emissions – driven by increasing direct and indirect energy requirements of households – will thus have substantial effects on global climate mitigation efforts. Direct energy use for cooking is expected to increase due to a switch from traditional to modern fuels. Electricity for lighting is becoming more and more prevalent also in rural India. Occupational imperatives on the labor market and private preferences require and lead to increased mobility that causes significant growth in private motorized transport. Further, indirect energy and emissions embodied in the

[1] This result holds approximately for two poverty lines. The first is a domestic, nutritional food poverty line following Datt and Ravallion (2011) based on Planning Commission (1993), the second represents the international \$ 1.25 PPP poverty line.

production of consumed goods have a growing importance as well. The relationship between aggregate income and CO_2 emissions on the country level has been extensively analyzed within the Environmental Kuznets Curve (EKC) literature (Dinda, 2004; Heil and Selden, 2001; Holtz-Eakin and Selden, 1995; Stern, 2004). For CO_2 and more general for greenhouse gas (GHG) emissions, there is no turning point observed with higher gross domestic products. On the household level, the effect of rising income on CO_2 emissions from consumption has been less frequently analyzed, particularly for developing countries. We contribute to this literature by deriving marginal propensities to emit (MPE) on the household level based on income elasticities of demand and emissions related to the products and energy consumed. We apply an environmentally extended input-output (IO) analysis in combination with household expenditure survey data from India for the years 2004/05 and 2011/12. For the analysis we calculate the carbon footprint of households and identify the respective emission drivers. By definition, household consumption induced carbon emissions can be explained by the expenditure levels, the spending shares and the consumption items' carbon intensity of production. By estimating household preferences through a consumer demand system we can assess whether consumption item choices tend to become more carbon-intensive with rising income levels and how important these dynamics of consumptions patterns are compared to the scale effect of higher total household expenditure. The remainder of the paper is as follows. After the literature review we present the IO analysis and the calculation of carbon footprints. In the results section we present a descriptive analysis of the carbon footprints and determine the income dynamics behind the carbon footprints and carbon intensity of consumption. Eventually we discuss the implications of our findings in the conclusion.

2.2 Literature review

Although our particular focus is on India and developing countries, most studies on carbon footprints focus on developed countries. For surveys of the literature concerning input-output analysis and the carbon footprint, see also Minx et al. (2009) and Kok et al. (2006). Generally, carbon emissions, which are closely related to direct and indirect energy requirements of households, have been the subject of research since the 1970s. Herendeen and Tanaka (1976) use input-output and household expenditure data to calculate energy requirements of U.S. households. Additional to energy intensities, GHG intensities have been calculated by Lenzen (1998b) for Australian final consumption. Based on IO-analysis and including other GHGs than CO_2 such as CH_4, N_2O, CF_4 and C_2F_6 it is found that most of the GHG emissions are ultimately caused by household purchases. One of the first studies calculating carbon footprints on a disaggregated household level, household expenditure data and IO derived carbon intensities have been used to calculate household carbon footprints for Australia (Lenzen, 1998a). Among the finding that per capita income is the main determinant of household energy and carbon requirements, it is found that rural households spend their income on more energy intensive commodities than households from metropolitan areas on average. Wier et al. (2001) analyze the carbon footprint of Danish households, identifying household characteristics with a significant influence on CO_2 emissions. Kerkhof et al. (2009) quantify CO_2 emissions of households in the Netherlands, UK, Sweden and Norway by combining a hybrid approach of process and input-output analysis with household expenditure data. Similar approaches are used by Bin and Dowlatabadi (2005) and Weber and Matthews (2008), both focusing on US households.

Drawing on a similar methodology for energy as Lenzen (1998b), Lenzen et al. (2006) focus on the role of income growth in a cross-country analysis. Their motivation is to characterise household consumption patterns with respect to their environmental implications and hereby search for evidence on the Environmental Kuznets Curve (EKC). Their findings support previous research in the EKC energy literature, as energy requirements increase monotonically with household expenditure but no turning point is observed. In general, the EKC literature describes the relationship of income and emissions with the marginal propensity to emit (MPE), which is usually found to be diminishing with income at slow rates (Holtz-Eakin and Selden, 1995; Ravallion et al., 2000). However, these cross-country studies have little to say about the relationship between emissions and income within countries, let alone dealing with demand side emissions. The argumentation behind the EKC is methodologically on a more aggregate level and the discussed mechanisms cannot be transferred to the household level. Although Ravallion et al. (2000) already emphasized the importance of consumer demand for non-linear effects of income of emissions, studies that deal explicitly with this question on the household level are rare. For transport related emissions Kahn (1998) and Cox et al. (2012) discuss the existence of an EKC on the household level but studies covering all direct and indirect household emissions are almost non-existent. As an exception, Golley and Meng (2012) calculate carbon footprints for urban Chinese households and find a slightly increasing MPE.

Carbon footprints for Indian households and earlier years have been calculated by Parikh et al. (1997) combining IO-data from 1989-90 and household data for the years 1987-88. Their paper presents differences in consumption patterns across income groups and their carbon dioxide implications. A main finding is that the rich have a more carbon intensive lifestyle with the urban emission levels being 15 times as high as those of the rural poor. Apart from carbon footprints, closely related energy requirements of Indian households have been calculated by Pachauri and Spreng (2011) for the years 1983-84, 1989-90 and 1993-94.

Based on IO-analysis, they find that household energy requirements have significantly increased over time identifying growing income, population and increasing energy intensity in the food and agricultural sectors as the main drivers. Based on this analysis, Pachauri (2004) presents cross-sectional variations in total household energy requirements. Using household consumption expenditure data for 1993-1994 matched with energy intensities calculated by Pachauri and Spreng (2011), an econometric estimation reveals income levels as the main factor determining variation in energy requirements across households.

Hertwich and Peters (2009) analyze the carbon footprint of nations by applying IO analysis with data from the Global Trade Analysis Project. Therewith they construct a multi-regional input-output model to estimate the carbon footprint based on four major GHGs measured in CO_2 equivalents. The focus is on eight expenditure categories, such as food, clothing and mobility, and their contribution to the national carbon footprint. They find a per capita carbon footprint of about 1.8t CO_2 equivalents for India in 2001.They also find that 95% of Indian emissions are from final consumption of households. Since we only focus on CO_2 emissions and different years, these results are hardly comparable to our results. The following analysis provides an update on carbon footprints in India and a detailed analysis of the relationship with consumption on the household level.

2.3 Methodology

2.3.1 Deriving the carbon footprint

We combine energy IO analysis with emission factors and household expenditures for goods and services to estimate the carbon footprint for Indian households. Therewith, we can trace the carbon content of each final consumption item back to its intermediates and account for the direct as well as indirect emissions from consumption. We focus on carbon emissions from fossil fuels since CO_2 emissions represent the largest share of GHG emissions and other GHG emissions are not available on the used detailed sectoral level. The method which has been applied is based on Leontief (1970) and we follow the approach of Proops et al. (1993) and Lenzen (1998b) summarized in Munksgaard et al. (2009). In a first step we estimate the CO_2 intensities (in local currency unit) of each sector of the Indian economy. We apply a single region IO model based on data from the Global Trade Analysis Project (GTAP). By using a single region IO model we account for direct and indirect emissions from goods produced and consumed in India as well as for emissions from imported goods.

IO tables for the year 2004 are from the Indian Central Statistical Organisation (CSO) which provide us with an $[j \times 1]$ vector of domestic output x by 130 sectors j, a $[j \times 1]$

vector of final demand y by 130 sectors j (which includes imports).[2] The $A[j \times j]$ matrix of the technical coefficients A reflect the input requirements of the jth sector of intermediates from other sectors measured in monetary units.[3] The domestic technology assumption is applied with the assumption that imported goods are produced with the same technology as local goods. We also assume that technology has not changed drastically between 2004 and 2011 since we use the same IO table to estimate the emission intensities of sectors for 2011.[4] Depending on the fuel type the CO_2 emissions per unit of fuel use are represented in the emission coefficient vector $c[m \times 1]$. The $[m \times j]$ energy use matrix E_{ind} represents the quantitative energy demand of the 58 sectors per monetary unit of intermediate output from other sectors. The energy use matrix E_{fd} represents the household's fuel quantitative use per monetary unit of final demand from 58 sectors.[5] Total emissions from consumption CO_2 would consist of direct $CO2_{fd}$ from final demand and indirect $CO2_{ind}$ emissions from energy use by each sector. In the first step we match the 130 sectors of our IO tables with the energy use data, which is aggregated to 58 sectors in order to get the energy intensity matrix E. Secondly, we match the 58 sector emission intensities with the corresponding expenditure categories from the household survey data. The data on household expenditure is rather disaggregated and we match all the approximately 340 expenditure categories with the corresponding emission intensities. Even though the IO tables contain information on monetary fossil fuel and electricity demand we still need to refer to the quantitative energy intensity data from GTAP to gain a more precise estimate on emissions per sector.

We analyze the sum of direct and indirect emissions from industrial sectors. Direct emissions from final demand can be characterized as follows:

$$CO2_{fd} = c' E_{fd} y \tag{2.1}$$

where c' represents the inverse emissions coefficient vector, E_{fd} is the energy use matrix and y is the final demand vector. Indirect emissions $CO2_{ind}$, which are divided into emissions from domestic production for domestic final demand, emissions from imported intermediates and emissions from imported final demand.[6] The emissions by sector can be estimated by multiplying the demand of each sector represented as vector y with the transposed emissions coefficients vector c and the industrial energy use matrix E_{ind} as well as the with the domestic

[2] The 130 sectors include administration and defence.

[3] All values are in local currency units at 2004 producer prices.

[4] This assumption is confirmed by the emission intensities per sector from the World Input Output Database (WIOD), which did not change drastically in India for available years between 2004 and 2009

[5] The data by the GTAP energy volume data is disaggregated into 58 sectors, which were matched with the 130 sectors from the Indian IO tables.

[6] Exports are excluded.

Leontief inverse $(I-A)^{-1}$:

$$CO2_{ind} = c'E_{ind}\Big[(I-A)^{-1}y_{\neq exp} + ((I-A_{tot})^{-1} - (I-A)^{-1})y_{\neq exp} + (I-A_{tot})^{-1}y_{imp_{\neq exp}}\Big] \tag{2.2}$$

where $A_{tot} = A + A_{imp}$, $y_{tot} = y + y_{imp}$ and $y_{\neq exp}$ is domestic final demand, I represents an identity matrix and A is the technical coefficients matrix, which mirrors the contribution of the intermediates to one final output unit. Additional to these direct and indirect production emissions, households directly use fuels which are unaccounted for in the IO analysis. With observed quantities in the survey data, we calculate direct carbon intensities for kerosene, liquefied petroleum gas (LPG), petrol and diesel.[7] Another correction is necessary for electricity emission intensities, due to the block-tariff nature of electricity expenditures. Since prices per kilowatt hour rise with the usage of electricity, we find no constant but household specific carbon intensities. Lower income households with small electricity demand have higher carbon intensities per currency unit than higher income households with large demand. The calculation is based on observed quantities of electricity demand.[8]

Direct emissions from fuel use $CO2_{fd}$ and direct and indirect production emissions $CO2_{ind}$ embedded in consumption (with the exception of electricity)can be estimated by:

$$CO2 = c'\Big[E_{fd}y_{hh} + E_{ind}\Big((I-A_{tot})^{-1}y_{\neq exp} + ((I-A_{tot})^{-1} - (I-A)^{-1})y_{\neq exp} + (I-A_{tot})^{-1}y_{imp_{\neq exp}}\Big)\Big] \tag{2.3}$$

In order to estimate the household carbon footprint we multiply the carbon intensity $\sigma = c'[E_{fd} + E_{ind}(I-A)^{-1}]$ per local currency unit of each industrial sector with the household expenditure for the respective category and sum up over all consumption categories for each household. Therewith we gain the household carbon footprint $CO2_{hh}$ for each household in tonnes (t) of $CO2$.

$$CO2_{hh} = \sum_{j=1}^{n}(\sigma_j * exp_j) \tag{2.4}$$

where i represents the household and j the different expenditure category. The household expenditure data for the carbon footprint calculation is from the National Sample Survey Organisation (NSSO) India, with a sample size of approximately 125000 and 100000 house-

[7] Direct carbon contents are 0.00255 t/l (kerosene), 0.00159 t/kg(LPG), 0.00231 t/l (petrol) and 0.00273 t/l (diesel).

[8] Electricity production carbon intensity is taken as 0.001003 t/kwh (IPCC, 2005)

holds in 2004/05 (61st round) and 2011/12 (68th round) respectively. Household expenditures are disaggregated into around 346 consumption items which we aggregate to 19 expenditure groups (for a description of expenditure groups see table 2.1 and the matching scheme with CSO IO tables for 2011/12, see table A.1).[9]

2.3.2 Income dynamics of the carbon footprint

The relationship between economic development and the environment has been divided into three components by the economic literature (Copeland and Taylor, 2005; Grossman and Krueger, 1994). First, the scale effect is simply the increase in pollution with economic activity. Second, the technique effect describes the pollution intensity of production activities. Third, the composition effect deals with the mixture of economic operations. Originally invented to describe the aggregate relationship between economic growth and environmental pollution, this classification can also be used for economic activity on the household level. By definition (equation 2.4), the household carbon footprint depends entirely on the consumption of goods and the carbon intensity of consumption goods. The total consumption size reflects the scale effect and the carbon intensity the technique and composition effect. With just one estimate of the production carbon intensities and assumed constant values over time between our used surveys, we focus exclusively on the scale and composition effect. Alternatively, the relationship of carbon footprints and income and household specific characteristics could be analyzed in a cross-section regression framework as demonstrated by Wier et al. (2001) and Pachauri (2004) for household energy requirements. Levinson and O'Brien (2015) estimate a parametric function of household local pollutant footprints depending on income and several household characteristics. They name this approach the estimation of environmental Engel curves and find generally concave curves for local pollutants for US households but do not include CO_2 emissions. However, this reduced form approach may has considerable drawbacks. The first originates from a theoretical standpoint. Households target their consumption at goods which fulfil their needs under the income constraint, while pollution represents an externality that is neither explicitly taken into account nor is it an aim to maximize or minimize the environmental footprint. Such an analysis is therefore more limited to an interpretation of correlations. Secondly, endogeneity can never be ruled out in this approach since the carbon footprint is explicitly defined as the sum of the product of group expenditures and carbon intensities. Total expenditures as a proxy for income are highly correlated with any other explanatory factor for carbon footprints including potential unobserved factors. The third drawback of this approach is the missing information about the

[9]The classification is very similar for 2004/05 and available upon request.

consumption categories driving the change in household carbon footprint at different points of the income distribution. While the coefficient for income explains the carbon intensity of consumption when all other variables are held constant, we have no information which consumption items are responsible for this change. We expect some categories to drive the carbon footprint more than others, revealing valuable information for further energy and climate mitigation policies. To deal with these issues we employ a structural model by estimating a household demand system for various consumption items. Since we do not have price data available for the household expenditure items, we assume constant prices and estimate Engel curves only dependent on income and socioeconomic characteristics of the households. The model to be estimated is a simple extended version of Working (1943) and Leser (1963) with a squared income term and has the following form:

$$w_{ij} = \alpha_j + \beta_{ij} log(y_j) + \lambda_{ij}(log(y_j))^2 + \varepsilon_{ij} \tag{2.5}$$

The necessity of including squared logarithmic terms for some expenditure items has been demonstrated in a series of empirical studies (Banks et al., 1997; Blundell et al., 1993; Hausman et al., 1995; Lewbel, 1991). They account for a higher degree nonlinear relationship between budget shares and income than is allowed for in some popular specifications of demand models such as the Translog (Christensen et al., 1975) and the Almost Ideal Demand System (Deaton and Muellbauer, 1980). In equation 2.5, w_{ij} represents the share of total expenditures allocated to the ith consumption category by the jth household, $logy_j$ the income of household j in logs and the error term ε_{ij}. With no income information available in the survey, we use total expenditures per household as a proxy for income. Aggregating household expenditures into 19 categories (see section 2.4), we estimate this system of equations with a feasible generalized nonlinear least squares two-step estimator. The demographic demand shifters household size, age and education are included in the α_{ij} term.

As the budget shares are defined as $w_i = \frac{exp_i}{y_i}$ it is convenient to obtain income elasticities relative to exp_i:

$$e_i = \frac{(\beta_i + 2\lambda_i log(y_i))}{w_i} + 1 \tag{2.6}$$

Deaton (1997) points to potential simultaneity bias, which is caused by richer households buying high quality products, which are more expensive. As households get richer they do not consume more of a certain good and cause more carbon emissions but they consume higher quality goods, which may not have to be related with higher carbon emissions than the lower quality items of the same consumption category. To partly account for this quality bias we split the sample for the analysis into rural and urban. Another problem is the occurrence of zero expenditures, which are less of an issue for daily requirement goods such as food but more so for education, medical and personal goods which are either infrequently purchased or never due to income constraints. We apply the correction procedure of Shonkwiler and Yen (1999), which is based on Heckman (1976, 1979). First, a household specific probit model is estimated with the outcome of 1 if the household consumes good i and 0 otherwise. For each household, the standard normal probability density function (pdf) $\Phi(z_{ih}, w_i)$ and the cumulative distribution function (cdf) $\phi(z_{ih}, w_i)$ are calculated by regressing w_i on a set of independent variables z_{ih}. Secondly, the pdf and the cdf are integrated into the system of equations as follows:

$$w_i^* = \Phi w_i + \varphi_i \phi \tag{2.7}$$

Based on (2.7), the new expenditure levels are calculated for each household in the sample. Accordingly, new footprints are calculated as:

$$CO2_{hh}^{sim} = \sum_{j=1}^{19} \sigma_j exp_j^{sim} \tag{2.8}$$

The difference between the simulated and the baseline footprint following a 1 percent increase in income can be directly interpreted as the income elasticity of CO_2 for the respective subsample. This elasticity can also be interpreted as a version of the marginal propensity to emit (MPE) on the household level. In order to understand the role of changing consumption patterns for the emission of CO_2, we decompose the changes of the carbon footprint into the share each consumption category has in explaining the rise of the footprint. The MPE is therefore directly decomposable into consumption items.

2.4 Results

2.4.1 Household CO_2 requirements

The average CO_2 emission intensities for 2011/12 and for 19 aggregate consumption groups and items are displayed in Figure 2.1. Emission intensities vary strongly between the consumption categories with the highest emission intensity per currency unit for electricity, followed by kerosene and LPG. Further, toiletry, medical and clothing as well as transport items exhibit relatively high carbon intensities due to the manufacturing process of those goods or direct energy use in the case of transport. Animal protein, which accounts for dairy as well as any kind of meat products or fish, exhibits a low carbon intensity since we only account for emissions from fossil fuels and not for other greenhouse gases such as methane or nitrous oxide. The carbon intensity of the category vegetables & fruits, which includes all non-animal agricultural produce, is higher than of animal protein since there is more input from other emission intensive sectors. We observe low emission intensities for education and vegetables, which contains all the agricultural goods apart from meat, dairy or fish. Since 2004/05, electricity is the only average carbon intensity which changed with a clear upward trend (Appendix Figure A.1). With a rising electrification rate, this is driven by relatively low electricity demand from lower income households and associated higher carbon intensities through the increasing block-tariff schedule.

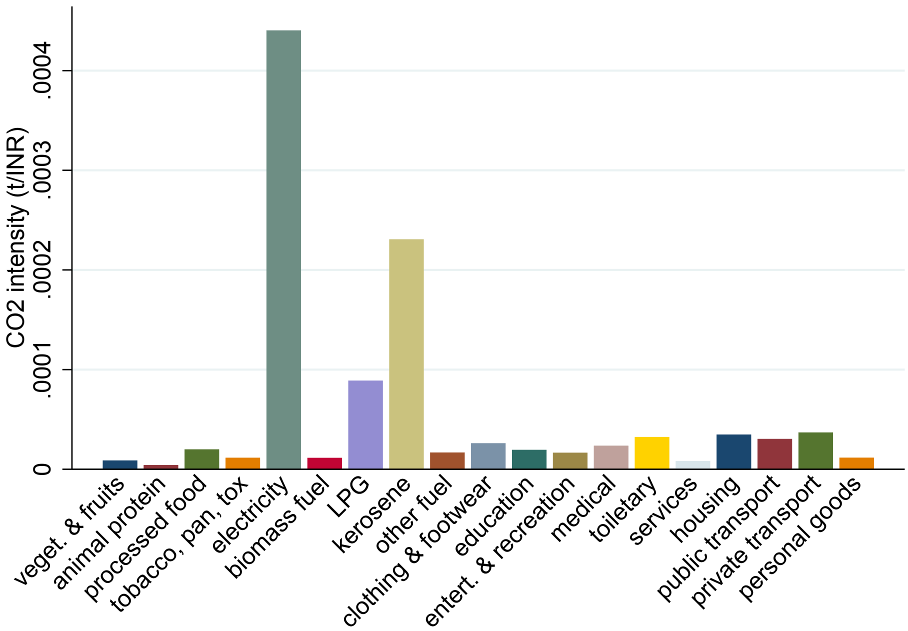

Fig. 2.1 Carbon intensities of expenditure Sub-Groups (2011/12)

Table 2.1 gives an overview on what households spent their income on in 2004/05 and 2011/12. The structure of the expenditure shares varies largely between rural and urban households. Rural households spent a larger fraction of their income on agricultural goods and a smaller share on housing (including rent) and transport than urban households. Table 2.1 also reveals that expenditure shares for vegetables and fruits were declining between the two time periods for both rural and urban households. Despite the increase in animal protein expenditures, total food budget shares decline with rising income as predicted by Engels law.

The resulting average per capita footprint is at 0.7t CO_2 in 2011/12, less than half the size of per capita CO_2 production emissions which are at 1.7t in 2012. This difference is due to smaller reported survey expenditures and smaller indicated total population in the survey, measured as the sum of individual weights. Regarding the difference between survey and national accounts data, there are a variety of reasons discussed in the literature from selection issues to item nonresponse (Deaton, 2005) other conceptual issues. There is also the possibility that the national accounts data has serious quality issues since the consumption aggregate is determined residually and definitions of consumption is different from the survey data (Datt et al., 2016; Deaton, 2005; Sen, 2000). As we have no reliable information on the exact nature of the bias in the used national accounts and survey data, we refrain from scaling the survey data with a constant factor to make it comparable with the national accounts. Such a procedure would have little influence on the further analysis which mainly focuses on carbon footprint changes over the income distribution.

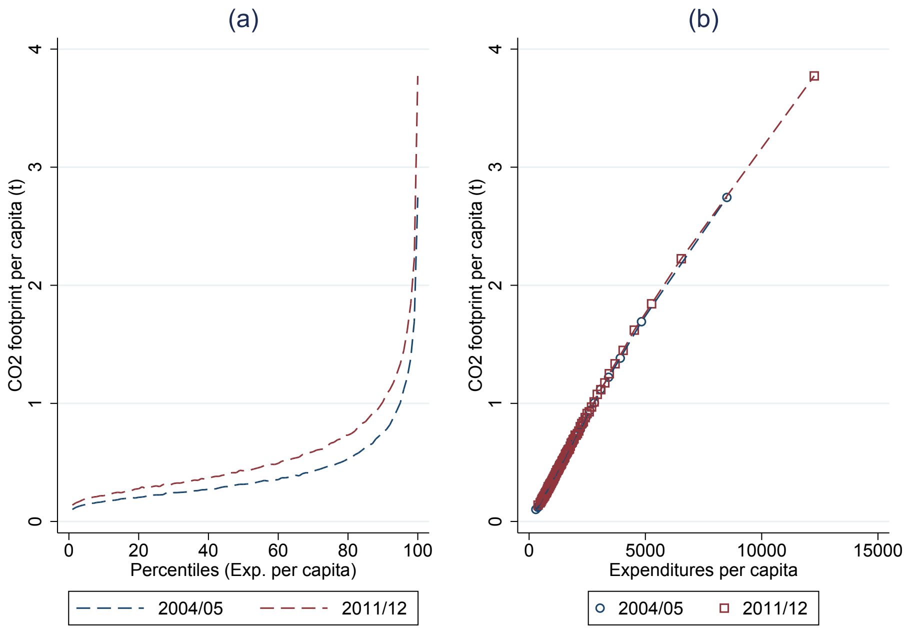

Fig. 2.2 Household carbon footprint per capita

We find large differences for carbon footprints over the income distribution as displayed in Figure 2.2. The 2011/12 average per capita carbon footprint of the 10 percent richest household is with 1.6 t CO_2 about 11 times higher than the carbon footprint of the poorest 10 percent with 0.15t CO_2. An almost linear relationship between per capita footprints and average per capita income per percentile can be observed for the bottom 80 percent of the population (Figure 2.2a). Behind this threshold, a clear nonlinear increase of footprints over income percentiles can be observed. Opposed to the optical impression, it does not imply a general nonlinear relationship between carbon footprints and income. The top income percentiles are much more compressed since they have a much larger income variation than low and middle income percentiles. Income and carbon footprints are in fact almost linearly related, with a slight concave curvature, displayed in Figure 2.2b. Between 2004/05 and 2011/12 growth in per capita carbon footprints grow along the same almost linear curve (Figure 2.2b) at the same real income level (in 2011 prices). Although it can be inferred that richer households are responsible for larger increases in carbon footprints, these absolute figures hide an important fact about the dynamics of emission growth over the population and over time. Despite the fact that annual average expenditure per capita growth rates have been larger for middle and high income households (Figure 2.3a), the carbon footprint per capita growth rates have been larger for lower income households. In fact, the growth rate in mean for carbon footprints is larger than for expenditures, indicating an average CO_2-expenditure elasticity larger than 1.

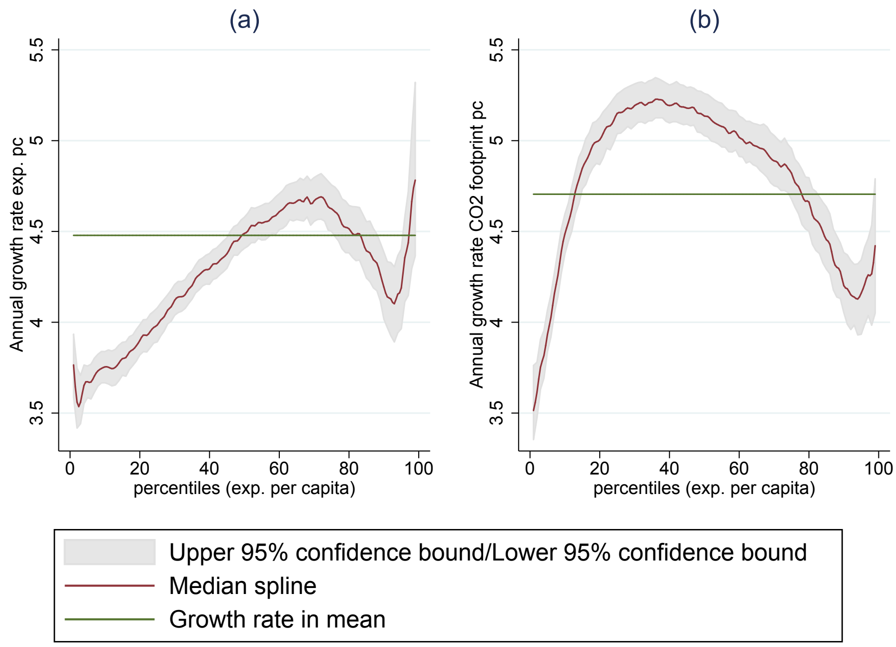

Fig. 2.3 Expenditure and carbon footprint per capita growth incidence curves (2004/05-2011/12)

The carbon footprints have therefore risen more than proportional with expenditure growth, a fact that can be explained by consumption patterns and the associated carbon intensity of consumption. Over the expenditure distribution, the carbon intensity of consumption is increasing (Figure 2.4a) but has been growing stronger for the bottom 60 percent of the expenditure distribution over the last years (Figure 2.4b).

Responsible for this increase in the carbon intensity is a shift towards more carbon intensive consumption goods. Due to the high carbon intensity, particularly for low demand, rising electrification rates explain most of this increase. The carbon intensity of consumption

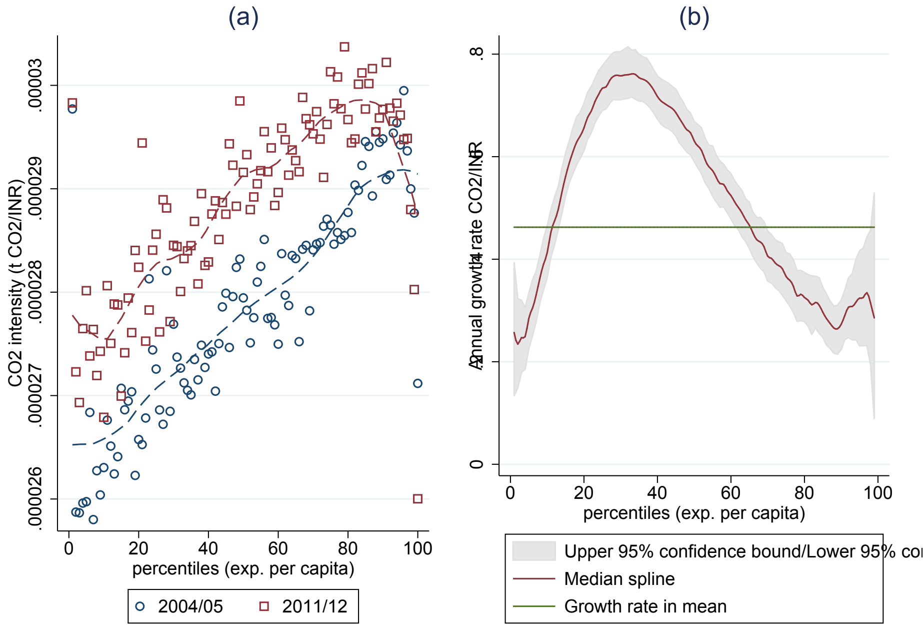

Fig. 2.4 Carbon intensity of consumption (2004/05 – 2011/12)

appears to have a certain income threshold when household shift their consumption towards less carbon intensive goods. Urban households appear to reduce the carbon intensity of consumption earlier than their rural counterparts. For a majority of the population however, it implies a more than proportional rise in carbon footprints when income increases. Beyond the size and composition of consumption varying with preferences at different income levels, other household characteristic may also be responsible for different carbon requirements. Urban households have on average a higher per capita footprint than rural households which also holds over the entire income distribution (Figure 2.5).[10] Beyond the location of the household in urban or rural areas, other sociodemographic factors have been frequently used in trying to explain within country cross-sectional variation in regression analyzes of energy use and CO_2 emissions (Pachauri, 2004; Wier et al., 2001). We opt for a nonparametric procedure and use kernel-weighted local polynomial smoothing to plot the carbon footprint per capita over income percentiles for different household characteristics (Figure 2.5). We observe a slightly higher pr capita footprint for households with older household heads above the 80th percentile. This might be due to higher direct energy needs of older households but the difference is small. Slightly higher footprints can also be observed for households with higher educated household heads, but differences are again negligible. Small but negligible

[10]Nonparametric distributional curves are calculated with kernel-weighted local polynomial smoothing using an epanechnikov kernel function with degree 0 and bandwith 1.15

economies of scale in consumption and energy use are present when comparing different household sizes over the income distribution. These findings confirm earlier studies that sociodemographic (and sociocultural) information is of little importance for the determination of household energy and CO_2 requirements (Pedersen, 2000; Stokes et al., 1994; Wier et al., 2001). Although available studies are from developed countries, there is little reason why demographic variables should play a larger role in developing countries as confirmed here. Despite the clear observed patterns, past trends of emissions embedded in consumption may not necessarily hold in the future. Particularly the electrification rate is projected to be close to 100 percent in the coming years, and initially large relative emission increases for lower income households may diminish. To provide an analytical tool how to evaluate the role of the different consumption items driving the carbon footprints, an Engel curve analysis is presented in the next section.

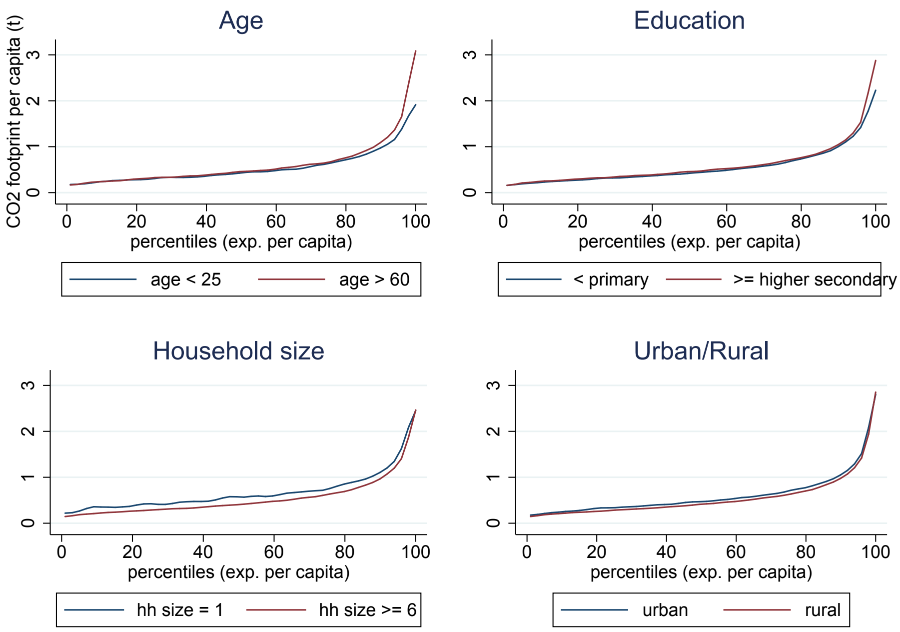

Fig. 2.5 Carbon footprints and sociodemographic factors (2011/12)

Table 2.1 Expenditure share of consumption categories

		1 veget. & fruits	2 animal protein	3 processed food	4 tobacco, pan, tox	5 electricity	6 biomass fuel	7 LPG	8 kerosene	9 other fuel	10 clothing & footwear
2004/05	Rural	0.40	0.10	0.06	0.03	0.02	0.06	0.00	0.01	0.01	0.08
	Urban	0.29	0.11	0.07	0.02	0.04	0.02	0.03	0.01	0.00	0.07
	National	0.37	0.10	0.07	0.02	0.02	0.05	0.01	0.01	0.01	0.08
2011/12	Rural	0.34	0.12	0.06	0.02	0.02	0.06	0.01	0.01	0.01	0.08
	Urban	0.26	0.11	0.06	0.02	0.04	0.01	0.03	0.01	0.00	0.07
	National	0.32	0.12	0.06	0.02	0.02	0.05	0.01	0.01	0.01	0.08

		11 education	12 entert. & recreation	13 medical	14 toiletary	15 services	16 housing	17 public transport	18 private transport	19 personal goods
2004/05	Rural	0.02	0.01	0.05	0.03	0.03	0.05	0.02	0.01	0.01
	Urban	0.05	0.02	0.05	0.03	0.05	0.08	0.03	0.03	0.01
	National	0.03	0.01	0.05	0.03	0.04	0.06	0.02	0.02	0.01
2011/12	Rural	0.03	0.01	0.06	0.03	0.04	0.04	0.02	0.02	0.01
	Urban	0.06	0.02	0.05	0.03	0.06	0.09	0.03	0.04	0.01
	National	0.04	0.01	0.06	0.03	0.05	0.06	0.03	0.03	0.01

2.4.2 Income and carbon elasticities of consumption

Income elasticities for income quintiles and urban and rural populations separately are calculated based on coefficients from equation 2.5. We calculate elasticities individually for households and calculate average values for quintiles, divided into urban/rural and weighted by the household expenditure share of total sample expenditures in the respective category. Table 2.2 displays urban income elasticities, which widely differ depending on the income level. As expected, elasticities for agricultural products and animal protein decline with rising income. The income responses for the high carbon intensive consumption items differ significantly between the items and over the expenditure distribution. Electricity is almost a luxury good for the bottom quintile and the elasticity stays close to one with rising income. Other domestically used direct energy items are necessities, opposed to transport expenditures which are clearly luxury goods at all expenditure levels.

For rural households, estimated consumption responses for income changes reflect differing preferences (Table 2.3). Public transport is estimated to be an inferior good at all income levels whereas private transport is quite a popular luxury good. Electricity income elasticities are also close to one for most households but describe electricity to be more of a luxury good for the top quintile. Lower income rural households also buy relatively more LPG than their urban counterparts when income rises. Considering less carbon intensive products, expenditures for housing are a luxury for rural households but less so than for urban households despite the on average smaller housing spending shares. Besides the size of income effects, also sample sizes differ considerably between rural and urban income groups. Due to a large urban-rural income disparity, the bottom three urban quintile samples are small, the same holds for the top rural income quintile sample. Transport is found to be a luxury good for all households, which is particularly important due to its high carbon intensity. Households in India are expected to increase spending on transport across all income levels. For domestically used energy, rural households are still catching up in demand and exhibit income elasticities close to one.

To understand the implications for carbon emissions, we calculate carbon footprint changes resulting from a 1 percent income increase which results in income elasticities of carbon footprints or the marginal propensity to emit (MPE). For the different population groups, the resulting total elasticities are all close to 1 but differ to some extent depending on the income level and living in urban or rural areas (Tables 2.4 and 2.4). An income elasticity of the carbon footprint of 1 would rule out any change in the carbon intensity of consumption and income would be the only driver. The pattern we observe from the estimation of demand is that on average all urban households increase their carbon footprint elastically, exhibiting an MPE slightly above 1.

Table 2.2 Income elasticities (urban)

	item group	quintiles 1	2	3	4	5
1	vegetables & fruits	0.78	0.71	0.63	0.53	0.11
		(0.001)	(0.001)	(0.001)	(0.002)	(0.007)
2	animal protein	1.15	1.06	1.00	0.94	0.70
		(0.003)	(0.002)	(0.001)	(0.001)	(0.005)
3	processed food	0.20	0.40	0.58	0.78	1.25
		(0.013)	(0.009)	(0.007)	(0.005)	(0.008)
4	tobacco, pan, tox	0.69	0.71	0.72	0.75	0.73
		(0.008)	(0.008)	(0.007)	(0.007)	(0.009)
5	electricity	0.98	0.96	0.95	0.94	0.90
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
6	biomass	0.67	0.63	0.58	0.56	0.59
		(0.007)	(0.009)	(0.012)	(0.013)	(0.018)
7	LPG	0.74	0.61	0.51	0.38	0.11
		(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
8	Kerosene	0.55	0.61	0.65	0.70	0.77
		(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
9	Other fuel and light	0.58	0.35	0.19	-0.01	-0.31
		(0.013)	(0.016)	(0.018)	(0.019)	(0.028)
10	clothing & footwear	0.94	0.92	0.90	0.88	0.81
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
11	education	2.35	2.00	1.75	1.57	1.35
		(0.043)	(0.034)	(0.023)	(0.015)	(0.010)
12	entertainment & recreation	0.63	0.62	0.61	0.64	0.83
		(0.009)	(0.005)	(0.004)	(0.003)	(0.003)
13	medical	1.62	1.58	1.56	1.52	1.43
		(0.015)	(0.013)	(0.011)	(0.010)	(0.010)
14	toiletary	0.82	0.81	0.80	0.79	0.73
		(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
15	services	1.45	1.41	1.39	1.35	1.27
		(0.005)	(0.004)	(0.003)	(0.002)	(0.002)
16	housing	1.62	1.51	1.42	1.32	1.21
		(0.007)	(0.006)	(0.005)	(0.003)	(0.002)
17	Public transport	2.58	2.24	2.08	1.93	1.75
		(0.026)	(0.019)	(0.016)	(0.012)	(0.010)
18	Private transport	3.92	2.66	2.11	1.92	1.63
		(0.120)	(0.084)	(0.051)	(0.033)	(0.019)
19	personal goods	2.31	2.21	2.09	1.91	1.51
		(0.091)	(0.093)	(0.084)	(0.070)	(0.049)

standard errors in parentheses

Table 2.3 Income elasticities (Rural)

		quintiles				
	item group	1	2	3	4	5
1	vegetables & fruits	0.71	0.63	0.56	0.43	0.03
		(0.001)	(0.001)	(0.001)	(0.002)	(0.011)
2	animal protein	1.31	1.19	1.13	1.08	0.92
		(0.003)	(0.002)	(0.001)	(0.001)	(0.005)
3	processed food	0.87	0.90	0.91	0.93	0.99
		(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
4	tobacco, pan, tox	0.77	0.81	0.83	0.85	0.88
		(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
5	electricity	0.89	0.89	0.90	0.92	1.01
		(0.001)	(0.001)	(0.001)	(0.001)	(0.003)
6	biomass	0.39	0.28	0.17	0.02	-0.24
		(0.004)	(0.005)	(0.007)	(0.011)	(0.023)
7	LPG	0.92	0.83	0.73	0.60	0.55
		(0.002)	(0.002)	(0.003)	(0.003)	(0.011)
8	Kerosene	0.41	0.38	0.40	0.43	0.68
		(0.003)	(0.004)	(0.004)	(0.006)	(0.012)
9	Other fuel and light	0.47	0.39	0.28	0.18	0.15
		(0.008)	(0.009)	(0.011)	(0.014)	(0.024)
10	clothing & footwear	0.94	0.90	0.87	0.84	0.68
		(0.000)	(0.001)	(0.001)	(0.001)	(0.005)
11	education	2.44	1.96	1.67	1.44	1.24
		(0.028)	(0.020)	(0.015)	(0.012)	(0.015)
12	entertainment & recreation	0.82	0.83	0.84	0.89	1.11
		(0.003)	(0.002)	(0.002)	(0.002)	(0.013)
13	medical	2.24	2.09	1.92	1.75	1.47
		(0.016)	(0.015)	(0.015)	(0.015)	(0.016)
14	toiletary	0.80	0.79	0.78	0.75	0.64
		(0.001)	(0.001)	(0.001)	(0.001)	(0.005)
15	services	1.36	1.28	1.24	1.20	1.12
		(0.003)	(0.002)	(0.002)	(0.001)	(0.002)
16	housing	1.26	1.29	1.29	1.28	1.29
		(0.002)	(0.002)	(0.002)	(0.003)	(0.007)
17	Public transport	-2.17	-1.60	-1.26	-1.03	-1.00
		(0.027)	(0.023)	(0.022)	(0.025)	(0.042)
18	Private transport	2.67	2.03	1.76	1.61	1.44
		(0.038)	(0.032)	(0.025)	(0.022)	(0.029)
19	personal goods	0.42	0.85	1.09	1.26	1.30
		(0.024)	(0.022)	(0.021)	(0.029)	(0.075)

standard errors in parentheses

Rural households have on average a MPE below 1, which is surprising considering the stronger growth in carbon footprints and carbon intensities due to higher electrification rates and direct energy use. While we expect a MPE above 1 particularly for low income households, the model has some limitations in correctly representing the discrete-continuous decision space for electricity and private transport demand. The MPE represents only continuous demand choices and the initial strong MPE rise through electrification is not incorporated. Despite this finding, the estimates for urban households, where electrification rates are fairly high, demonstrate how household carbon footprints and income is related. Once households have access to electricity, the MPE will unlikely to fall below 1 in the short- to medium-run in India.

Lower income household's carbon emissions stem to a large part from the agricultural sector. The MPE for vegetables and fruits is the second highest for these households, particularly in rural areas, but it is quickly declining with rising income. Urban households are increasingly buying processed food and do even more so with rising income at all income levels. Processed food contributes up to 6 percent of the rise in carbon footprints for urban households, an effect driven by very large income elasticities in this relatively low carbon intensive consumption category. The additional emissions from total food expenditures are continuously declining for all households in urban and rural areas down to 9 percent of the total increase. The largest item specific MPE can be found for electricity across all income levels and urban and rural areas. Up to 35 percent of the increase in footprints can be explained by higher direct energy use for electricity. As discussed above, urban households have higher MPEs than their urban counterparts, which directly results from higher electricity access rates. For all other domestically used energy, the item specific MPEs fall with rising income as LPG and kerosene demand does not rise infinitely. While emissions from food and domestic energy (except electricity) become less important with income growth, high elasticities drive emission growth from housing and particularly transport expenditures. The housing share of the total emission increase resulting from income growth increases from 10 to 15 percent for urban households from the first to the fifth quintile. Exceptionally strong is the MPE for private transport, driven by the luxury good character for all households. Rural households show relatively stronger footprint increases resulting from income growth. Up to 18 percent of the total emission rise can be explained by private transport demand. Urban households exhibit smaller MPEs for private transport but still major demand increases, reflecting their already higher consumption level. Emissions from direct energy use are sure to grow further for all income groups due to elastic income elasticities for electricity and transport with associated high carbon intensities. However, the growing share of direct energy use in carbon footprints growth does not imply that all other goods are becoming unimportant for emissions. Even for the top urban quintile, indirect emissions through the production of goods account for 50 percent of the emission increase. Although non-energy consumption items are less carbon intensive, they constitute the major share in total consumption and will continue to contribute significantly to rising carbon footprints. They are likely to contribute more when energy needs reach a saturation level where households do not need more energy for lighting, cooking, the operation of durables or transport. For domestically used energy such as LPG and Kerosene, this diminishing role can already be observed. Our derived estimates show that this saturation level might be in a very distant future for electricity and private transport, since both the urban and rural top quintiles show high income elasticities for these items.

Based on the estimation of consumer demand, the composition effect from the consumption side is not the most important factor, but is expected to play a role for current and future emission growth. On top of the scale effect, household demand for electricity and private transport is likely to let CO_2 emissions rise more than proportional with income growth.

Table 2.4 MPE Engel curve estimates (urban)

		quintiles				
	item group	1	2	3	4	5
1	vegetables & fruits	0.105	0.075	0.057	0.040	0.014
2	animal protein	0.018	0.019	0.019	0.017	0.012
3	processed food	0.012	0.018	0.027	0.036	0.065
4	tobacco, pan, tox	0.007	0.007	0.008	0.008	0.007
5	electricity	0.326	0.349	0.337	0.329	0.289
6	biomass	0.017	0.010	0.005	0.002	0.001
7	LPG	0.042	0.053	0.051	0.039	0.011
8	Kerosene	0.055	0.038	0.029	0.020	0.009
9	Other fuel and light	0.005	0.002	0.001	0.001	0.000
10	clothing & footwear	0.076	0.066	0.061	0.057	0.048
11	education	0.043	0.048	0.055	0.062	0.075
12	entertainment & recreation	0.004	0.006	0.007	0.007	0.008
13	medical	0.050	0.051	0.054	0.056	0.065
14	toiletary	0.028	0.025	0.024	0.022	0.018
15	services	0.016	0.017	0.018	0.020	0.026
16	housing	0.110	0.107	0.113	0.127	0.150
17	Public transport	0.052	0.059	0.061	0.061	0.062
18	Private transport	0.032	0.045	0.069	0.092	0.146
19	personal goods	0.005	0.006	0.007	0.010	0.018
	Total	1.004	1.003	1.003	1.004	1.025

Table 2.5 MPE Engel curve estimates (rural)

	item group	quintiles 1	2	3	4	5
1	vegetables & fruits	0.119	0.084	0.062	0.040	0.013
2	animal protein	0.024	0.028	0.028	0.026	0.020
3	processed food	0.047	0.046	0.042	0.041	0.046
4	tobacco, pan, tox	0.012	0.012	0.012	0.012	0.012
5	electricity	0.200	0.250	0.266	0.264	0.256
6	biomass	0.017	0.009	0.005	0.002	-0.001
7	LPG	0.008	0.022	0.032	0.037	0.027
8	Kerosene	0.055	0.031	0.023	0.014	0.010
9	Other fuel and light	0.004	0.003	0.002	0.001	0.001
10	clothing & footwear	0.095	0.082	0.073	0.065	0.047
11	education	0.037	0.041	0.044	0.053	0.057
12	entertainment & recreation	0.003	0.006	0.008	0.009	0.011
13	medical	0.098	0.097	0.097	0.100	0.114
14	toiletary	0.030	0.028	0.025	0.023	0.017
15	services	0.020	0.020	0.020	0.020	0.021
16	housing	0.080	0.081	0.084	0.090	0.108
17	Public transport	-0.060	-0.057	-0.049	-0.042	-0.036
18	Private transport	0.034	0.053	0.076	0.115	0.183
19	personal goods	0.001	0.003	0.005	0.009	0.026
	Total	0.825	0.838	0.855	0.879	0.930

2.5 Conclusion

Based on input output analysis matched with expenditure data as well as consumer demand analysis, we have investigated the consumption dynamics behind the growing carbon footprints of Indian households between 2004/05 and 2011/12. By estimating the income elasticity of major groups of consumption items, we are able to analyze the effect of changes in the composition of household consumption. We find that the scale effect of total household income is the major driver of household emissions and dominates the composition effect of consumption shifts. Particularly urban households exhibit MPEs larger than 1 reflecting shifts in consumption patterns towards a higher carbon intensity of consumption. An important driver behind this shift is higher demand for electricity with income elasticities close to 1 for all urban income groups. Private transport is estimated to be a luxury good for both rural and urban households and adds to the rising carbon intensity of consumption. Indirect energy use remains an important factor in determining the size and growth of the carbon footprints in India. The fact that staple and processed foods contribute significantly to footprint increases for low income households is a reminder how many households in India are still poor despite all the improvements over the last decades. Additionally to the observed consumption dynamics, we find only minor differences in carbon footprints caused by sociodemographic characteristics of households. Households thus share very similar preferences and increase their consumption for all items with accelerated growth for direct energy use for cooking, lighting and transport. Considering that currently low income households use far less energy than high income households we expect convergence over time to occur. This, in turn, is likely to imply that the speed of CO_2 emission growth and energy use may very well be accelerated in the near future. Calculating emission increases by assuming a unitary relationship between income and CO_2 emissions is set to underestimate the emission growth that will come from the energy thirsty population. The relationship between income growth and carbon emissions is likely to be described by an elasticity around or even above 1 in the short- to medium-run, as electricity and private transport demands have not reached observable saturation levels. The demand for these energy intensive goods quickly increases with income as millions of Indians are striving to drive cars and use convenient household appliances for their homes. Our analysis thus clearly points to priority areas for serious mitigation efforts in India: The electricity and transport sectors.

Chapter 3

Poverty and Distributional Effects of a Carbon Tax in Mexico

3.1 Introduction

Developing countries contribute a rising share to the worldwide emission of greenhouse gases. Mainly responsible for this growth in emissions are middle income countries with sustained economic growth rates while low income countries still exhibit relative small emissions per capita (Olivier et al., 2015). Among the group of middle income countries, Mexico, as an upper middle income and fairly advanced country, has become one of the most significant emitters of CO_2 in absolute and per capita terms recently. In 2014, it was ranked the 15th biggest economy (World Bank, 2016) and the 12th biggest carbon emitter in the world with more economic growth and fossil fuel intensive energy use to be expected in the future. Mexico started to voluntarily commit itself to greenhouse gas emission reduction targets in 2010 at the Cancun Climate Change Conference. In 2013, the government launched additional and further reaching reforms to the Mexican energy markets and thus prepared the ground for a green fiscal reform (Metcalf, 2015). In October 2013, the Mexican Congress approved the Government's proposal of a tax on the sale and import of fossil fuels which came into effect on January 1, 2014, making Mexico the first non-developed country to adopt such a policy. The price of the proposed carbon tax was calculated by weighting the carbon price of various international markets and the carbon content of each fossil fuel sold in Mexico using emission factors of the combustion process. The Mexican Congress approved different tax rates for distinct fossil fuel types with prices ranging between 5.80 - 46.42 Mexican Pesos (MXN) per tCO_2 (0.45 - 3.63 USD) (Belausteguigoitia, 2014). This implies a weighted average of MXN 43.10 per tCO_2 (USD 3.37). However, the tax is not levied on all emissions but only on those generated by fossil fuels other than natural gas and jet fuel. The risks of introducing a carbon tax for Mexico are identified as rising poverty through higher consumer prices, competitiveness losses of the Mexican industry and associated negative effects on the economy, wages and unemployment. Although Mexico is a middle income country, the introduced carbon price is relatively low in international comparison. As a result, effects on the CO_2 emission level and household welfare can generally be expected to be small. This however will not hold for expected higher future tax rates. In 2015, Mexico submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015 as the first developing country. Although the instruments to realize the planned emission savings are not explicitly mentioned, an increase in the carbon price appears as one highly suitable candidate. For Mexico, we do not find empirical evidence on the effects of a carbon tax in the literature. Gonzalez (2012) uses an analytical general equilibrium model to simulate a stylized carbon tax scenario for Mexico and finds that the direction of the effect is determined by the way the tax revenue is recycled. Redistribution towards food subsidies would lead to an overall progressive effect. We try to fill the gap in the literature by using an input-output model to calculate carbon intensities of various product categories and match the production side with consumption expenditure on the household level in order to determine the impact of carbon tax scenarios on household welfare. Besides calculating welfare effects for the current tax regime in place, we add scenarios including more CO_2 emissions from natural gas, jet fuel and other greenhouse gas emissions from methane (CH_4) and nitrous oxide (N_2O). We also include redistribution scenarios and check for welfare effects of border tax adjustments. The rest of the paper proceeds as follows. In section 3.2 we describe the methodology of the input-output model and the integration with the household consumption side used in the analysis. In section 3.3, general trends in emissions, energy use, consumption and poverty are supplied as background material for the analysis in section 3.4. We briefly discuss results and conclude in section 3.5.

3.2 Methodology

Our analysis consists of two steps, which have been applied in the previous literature on welfare effects of energy and climate policies (Labandeira and Labeaga, 1999, 2002). First, we calculate sector specific price changes following a taxation of CO_2 emissions by drawing on an environmentally extended input-output model. In the second step the price changes are translated into welfare effects on the household level.

3.2.1 Input-output analysis and price changes per sector

We obtain carbon intensities of 34 production sectors (table 3.1) by combining input-output tables with energy and emission data taken from the World Input Output Database (Timmer et al., 2015).

The resulting carbon intensities per production sector contain direct as well as indirect emissions from other sectors.[1] By assumption, production is described by a Leontief production function which implies no substitution between sectors so that price increases are fully shifted towards consumers. The model is theoretically valid for small tax changes in the short-run but increases in uncertainty with time and the size of the tax. For calculating the carbon intensities we follow Proops et al. (1993) and distinguish between different fuel types as these naturally contain different amounts of CO_2 per physical unit.[2] Total fossil fuel use per energy carrier is represented by F_f, whereby f indicates the type of fuel and represents an element of the vector f showing the fuel quantities used in production per sector. The carbon content per physical unit of the respective fuel is e_f and multiplying this vector by f yields total production CO_2 emissions C_{ind}:

$$e'f = C_{ind} \tag{3.1}$$

The intensity of fuel use in production c_{if} is defined as the ratio of the quantity of fuel type f used in sector i, F_{if}, and the sector's i total output X_i:

$$c_{if} = \frac{F_{if}}{X_i} \tag{3.2}$$

The product of the transposed fuel intensity matrix C and the total demand x gives the vector of production fossil fuel use f, i.e. $C'x = f$. Multiplying both sides by the carbon content per fuel unit e' and recalling equation 3.1 then describes the components of production CO_2 emissions:

$$e'C'x = e'f = C_{ind} \tag{3.3}$$

The elements of $e'C$ can be termed "direct carbon intensities" as they reveal how much CO_2 is emitted per unit of total output by each sector. The inclusion of CH_4 and N_2O in the analysis provides us with intensities of carbon equivalents, reflecting the gases global

[1] The WIOD data contains 35 sectors, but we eliminate the 35th sector ("Private Households with Employed Persons") due to insignificant contribution to total production and energy use.

[2] Fossil fuels included are hard coal, brown coal, coke, diesel, gasoline, light fuel oil, fuel oil, naphtha, other petroleum and other gases excluding natural gas.

Table 3.1 WIOD sector description

sector	sector description
1	Agriculture, Hunting, Forestry and Fishing
2	Mining and Quarrying
3	Food, Beverages and Tobacco
4	Textiles and Textile Products
5	Leather and Footwear
6	Wood and Products of Wood and Cork
7	Pulp, Paper, Printing and Publishing
8	Coke, Refined Petroleum and Nuclear Fuel
9	Chemicals and Chemical Products
10	Rubber and Plastics
11	Other Non-Metallic Mineral
12	Basic Metals and Fabricated Metal
13	Machinery, Nec
14	Electrical and Optical Equipment
15	Transport Equipment
16	Manufacturing, Nec; Recycling
17	Electricity, Gas and Water Supply
18	Construction
19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
22	Hotels and Restaurants
23	Inland Transport
24	Water Transport
25	Air Transport
26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
27	Post and Telecommunications
28	Financial Intermediation
29	Real Estate Activities
30	Renting of M&Eq and Other Business Activities
31	Public Admin and Defence; Compulsory Social Security
32	Education
33	Health and Social Work
34	Other Community, Social and Personal Services

warming potential.[3] Since CH_4 and N_2O emissions are transformed to CO_2 equivalent emissions, we continue to use the term carbon also when other gases are included. Finally, economic policy is more concerned with final demand and not exclusively with production x. Equation 3.3 has thus to be transformed in terms of final demand using the Leontief inverse $(I-A)^1$. Recalling total production $x=(I-A)^1y$ and substituting for x into equation 3.3 gives:

$$e'C'(I-A)^{-1}y = C_{ind} \tag{3.4}$$

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

$$CI_{ind} = e'C'(I-A)^{-1} \tag{3.5}$$

Equation 3.5 provides us with a new vector of CO_2 intensities which contains the direct carbon emissions, resulting from direct production emissions in the respective sector, plus the indirect carbon emissions, caused by the release of carbon emissions in the production of intermediate inputs in the production process of goods, per unit of final demand y. In order to determine the carbon content of each fuel, the WIOD data takes CO_2 emission factors from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and from the United Nations Framework Convention on Climate Change (UNFCCC) emissions reporting, as especially the latter also report country specific emission factors. Additionally to production emissions, households have direct demand for fuels and associated direct emissions C_{dir} which are not captured in the input-output framework. Total emissions from household consumption is the sum of direct and indirect emissions from consumption and energy use:

$$C = C_{dir} + C_{ind} \tag{3.6}$$

The carbon intensity of energy items with direct emissions such as fuels, could be calculated on the basis of observed quantities and physical emission factors. In the absence of observed quantities, we calculate these by using price per fuel unit data from the Instituto Nacional de Estadística y Geografía (INEGI), calculate direct emissions C_{dir} and obtain direct carbon intensities $CI_{dir}(tCO_2/MXN)$. Total demand carbon intensities per sector are then:

$$CI = CI_{dir} + CI_{ind} \tag{3.7}$$

[3]Global warming potential factors under the assumption of climate-carbon feedbacks and 100 year time horizons are 28 for CH_4 and 265 for N_2O (IPCC, 2013).

For non-fuels, equation 3.7 simply reduces to CI_{ind}. Depending on the scenario, final demand can either exclude imports or include them in a border tax adjustment scenario. In the latter case, we assume imports exhibit the same carbon intensity in production and are taxed like domestic goods. In a next step, we receive a vector of sector specific carbon taxes by multiplying the general carbon tax rate μ with the sector specific CO_2 intensity:

$$t = \mu * CI \tag{3.8}$$

Each sector specific ad valorem tax rate t_i can be directly interpreted as the sector specific price change relative to the base price p_{i0}:

$$(1+t_i)p_{i0} = p_{i1} \Leftrightarrow t_i = \frac{p_{i1}}{p_{i0}} - 1 \tag{3.9}$$

We convert basic prices to consumer prices using data on the net tax rates per sector provided in WIOD's national supply and use tables. The most recently available tables are from 2011 for the IO and 2009 for the energy and emission data.

3.2.2 Effects on household welfare

The total effect on household welfare in our specification depends on the impact of sectoral price changes on expenditures. Household expenditures are taken from the 2014 Encuesta Nacional de Ingreso y Gasto de los Hogares (ENIGH) available from INEGI. To link the production with the consumption side, we assign all expenditure items to the 34 production sectors (table B.2 in Spanish language, Appendix). Matching is done on the basis of expenditures item names and assigned description from the questionnaire. In order to assess distributional implications we calculate first-order welfare effects relative to total expenditures per household.[4] This is done by multiplying the consumption category specific carbon taxes with household expenditure shares:

$$\Delta w_{hi} = w_{hi} * t_i \tag{3.10}$$

to obtain the change in budget shares per consumption category. We use the sum of changes $\sum w_{hi}$ as the welfare loss, defined as the percentage share of total household expenditures. For the effects on poverty, we calculate absolute welfare effects and subtract them from household income, since domestic poverty lines are constructed with current income measures

[4]Second-order effects, including substitution away from and between goods, are naturally a superior measure of welfare effects but are hard to quantify here. Since our analysis is mostly concerned with the energy and carbon content of goods, estimating demand elasticities for a system of 34 sectors based on the IO classification would require extremely detailed price information which was unavailable to the authors.

(CONEVAL, 2014). All absolute effect are calculated on a per capita basis to facilitate the analysis across different household sizes.

3.2.3 Scenarios

Apart from the expenditure shares on certain goods and the size of the tax, welfare effects finally depend on the tax base, which is the share of emissions covered by the tax regime. The current legislation taxes CO_2 emissions from energy sources and excludes natural gas, jet fuel and non-energy emissions. The first scenario (A) reflects this current legislation scheme. Since natural gas is a major energy source in the electricity sector, we simulate the inclusion in the second scenario (B). Thirdly, reflecting the fact that climate change is a result of rising greenhouse gas emissions and not exclusively of energy CO_2 emissions alone, we add methane (CH_4) and nitrous oxide (N_2O) plus jet-fuel and non-energy CO_2 emissions to the calculation. Besides the share of greenhouse gas emissions by a tax, the actual tax size is crucial in each scenario. Setting the tax rate to an amount that captures marginal damages resulting from climate change has created major dispute in the literature (Pindyck, 2013). Considering the problematic calculation of the social cost of carbon we offer lower and upper bound tax rates of 20 and 50 USD per ton CO_2/CO_2e.[5] [6] In the first scenario, we additionally simulate a simplified version of the actual "carbon tax" that was introduced in 2014. Instead of working with a number of single fuel taxes, we set a uniform carbon tax of 3.5 USD/tCO_2 which is close to the implicit tax in place and facilitates comparisons with larger tax rates and other carbon tax regimes in the international context.[7] The 20 USD tax can be seen as a short term interpretation of the carbon tax as a major policy tool to achieve Mexico's INDC. The upper bound of 50 USD adds to the understanding of how larger tax rates affect household welfare. We calculate total tax revenues on the basis of the carbon intensity vector and the scaled 2014 consumer expenditures. Our derived tax estimates are therefore a projection for 2014 and exclude the taxation of exports, which is in line with our model assumptions.[8] Two redistribution scenarios are simulated, which includes a stylized lump-sum transfer per household over the entire population and a transfer of a share of the tax revenue to recipients of the social welfare program PROSPERA (formerly known as Oportunidades and rebranded as PROSPERA in late 2014).

[5]In the absence of clear scientific guidance on the exact social cost of carbon, these values will always be somewhat arbitrary.

[6]Annual average exchange rate 13.29 MXN/USD (International Monetary Fund, 2016).

[7]We also simulated the "real" carbon tax by calculating sector specific price changes based on the multiple of fuel taxes. As results do not differ significantly, we did not report them but they are available from the authors upon request.

[8]Official Mexican government estimates are slightly different due to differences in the calculation method, e.g. exports are taxed.

3.3 Emissions, consumption and poverty

Total carbon emissions of the Mexican economy have been rising steadily over the last years (Figure 3.1). Since the beginning of the 1970s, emissions have increased by over 350 percent, reflecting both per capita economic and large population growth. On average, income per capita has increased by over 80 and carbon emissions per capita by over 100 percent. This unequal growth rates can be linked to the rising carbon intensity (CO_2/GDP) of the economy until the 1990s; since then we observe a decline accompanied by more efficient energy use. Although the economy became less carbon intensive, energy efficiency improvements since 2000 have been small. If Mexico wants to change its growth path towards a low carbon pathway as discussed in its national climate strategy and its INDC pledges, a massive decarbonization of the energy system is the major challenge.

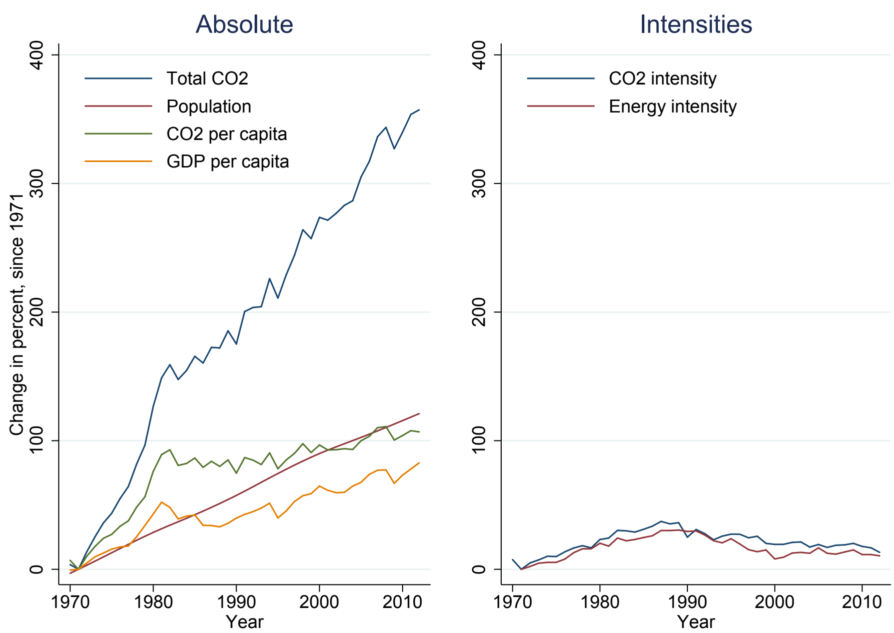

Fig. 3.1 CO_2 emissions, GDP and CO_2 intensities Mexico

Carbon emissions and intensities per production sector reveal more detailed dynamics in light of the overall slight decline (table 3.2). The utilities sector including electricity, gas and water supply has the highest emission total as well as emission intensity in 2009. Other sectors with high carbon intensities like water transport are less important in terms of direct emissions and even less so for household consumption. Inland and air transport play a bigger role but the latter is excluded from the current carbon tax legislation which implies zero price changes for households.

Table 3.2 Sectoral CO_2 production emissions and CO_2 intensities (Scenario B)

sector	CO2 (kt)			CO2 intensity (kt/MXN)		
	2009	change 1995-2009	% change	2009	change 1995-2009	% change
1	20829.2	3310.59	18.9	36.52	0.48	1.32
2	28501.36	12996.07	83.82	26.17	1.65	6.74
3	4742.34	-986.9	-17.23	17.48	-5.39	-23.58
4	2654.53	70.84	2.74	24.26	-0.15	-0.62
5	411.09	-115.36	-21.91	15.64	-1.92	-10.92
6	442.26	-275.22	-38.36	23.52	-6.81	-22.45
7	3102.72	636.81	25.82	24.03	1.57	6.97
8	31112.55	5502.69	21.49	52.5	-21.26	-28.82
9	9650.42	-3377.63	-25.93	27.93	-8.52	-23.37
10	1481.2	-83.21	-5.32	23.39	-4.6	-16.44
11	24279.19	7282.68	42.85	107.12	8.23	8.32
12	14053.75	-794.34	-5.35	38.5	-12.59	-24.63
13	816.03	101.63	14.23	15.35	-3.44	-18.3
14	3068.47	729.92	31.21	11.23	-1.56	-12.19
15	1721.49	395.03	29.78	10.1	-1.55	-13.33
16	2955.43	850.44	40.4	23.87	-2.15	-8.25
17	107813.29	32436.2	43.03	290.91	-151.67	-34.27
18	11732	6325.56	117	20.33	-3.34	-14.12
19	2118.31	737.27	53.39	17.25	-0.46	-2.58
20	2800.13	960.17	52.18	7.63	-1.14	-12.99
21	8708.97	3109.77	55.54	12.1	-1.12	-8.47
22	6039.58	1313.3	27.79	24.78	-2.83	-10.24
23	23689.76	8221.65	53.15	29.36	-2.1	-6.66
24	2237.76	266.55	13.52	147.31	-5.01	-3.29
25	8254.4	2006.94	32.12	86.15	-45.9	-34.76
26	1965.47	523.14	36.27	18.45	-4.58	-19.87
27	2074.73	569.84	37.87	8.23	-2.38	-22.44
28	907.06	417.77	85.38	4.16	0.65	18.65
29	826.02	344.42	71.52	3.59	-0.62	-14.69
30	5427.32	3451.16	174.64	9.13	-1.14	-11.08
31	5222.88	1301.03	33.17	15.48	-5.24	-25.27
32	6886.26	1976.5	40.26	11.69	-4.36	-27.16
33	2509.07	798.18	46.65	10.89	-2.24	-17.07
34	2244.8	402.36	21.84	14.99	-2.73	-15.4

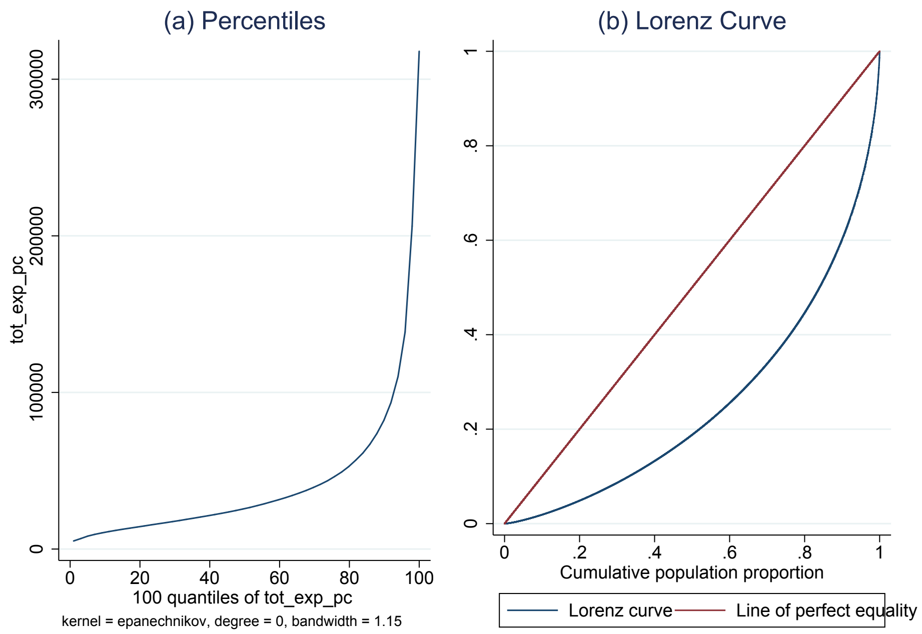

Fig. 3.2 Household per capita expenditures Mexico (2014=

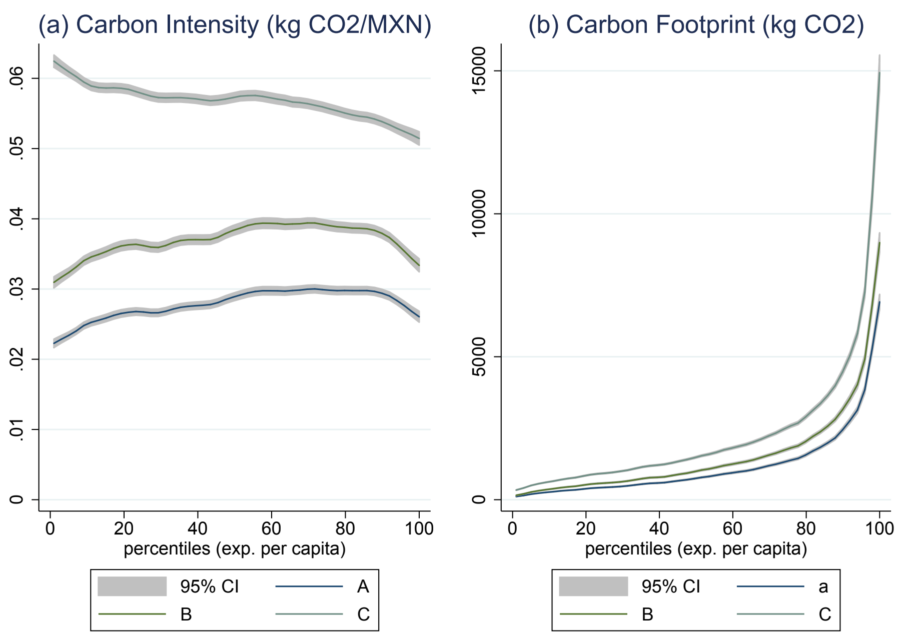

Fig. 3.3 CO_2 intensity of expenditures and CO_2 footprints Mexico (2014)

The observed overall decline in the carbon intensity can mainly be ascribed to the utilities sector, which exhibits a large decrease in absolute terms and of 34 percent relatively from 1995 to 2009. This decline can be largely ascribed to a shift from oil to gas in the power sector. Based on the analysis of overall carbon intensities, we would not expect the carbon intensity to change by great amounts from 2009 to 2014 and use the 2009 carbon intensities, deflated to the 2014 price level, for further analysis. Finally, a decline in the carbon intensity is no guarantee for decreasing emissions as can be observed from table 3.2. However, total emissions would have been higher without reductions in the carbon intensity, which has mainly happened in the energy and manufacturing sectors. Although we observe changes in the carbon intensity per sector until 2009, and the used household survey data is from 2014, we refrain from extrapolating an observed trend per sector to receive a vector of projected carbon intensities for 2014. Declines over time depend on the transformation towards more low carbon energy sources, information which is unavailable to the authors for recent years.

For the calculation of welfare effects relevant consumption expenditures are quite unequally distributed over the population. In 2014, total consumption expenditures of the top 10 percent of households are about 20 times higher than the bottom 10 percent expenditures (figure 3.2 a). We find that 50 percent of the population have less than a 20 percent share of total expenditures (figure 3.2 b), over 60 percent of all expenditures can be accounted to just 10 percent of the population at the top of the expenditure distribution.

High expenditure inequality already provides an indication for distributional impacts of consumption taxes in absolute terms. In relative terms, tax payments grow in proportion to the carbon intensity of consumption. We check the latter by calculating household specific carbon footprints for our three scenarios and relate these to household expenditures. The carbon intensity of consumption increases until the 50th percentile when only CO_2 emissions from energy use are taxed (Scenario A and B).[9] It decreases again at the 90th percentile, reflecting a shift to more service and less energy intensive consumption items (figure 3.3 a). This decline is quite moderate and can't make up for the quantity increase in consumption, reflected in high carbon footprints for high expenditure households (figure 3.3 b). Remarkably, the carbon intensity declines over the expenditure distribution when CH_4 and N_2O are taxed additionally to CO_2 emission from energy. The importance of CH_4 and N_2O intensive goods such as food in the consumption basket declines with income.

Although the welfare effects in our model depend on expenditure patterns, poverty effects finally depend on the definition of poverty lines as well. We calculate Foster-Greer-Thorbecke (FGT) poverty indices on the basis of poverty lines provided by the Consejo Nacional de

[9] Nonparametric distributional curves are calculated with kernel-weighted local polynomial smoothing using an epanechnikov kernel function with degree 0 and bandwith 1.15

Evaluacion de la Politica de Desarrollo Social (CONEVAL, 2014). Two distinct poverty lines are used. The first describes a minimum well-being standard of an individual which corresponds to the value of the food basket per person per month (Bienestar minimo - Canasta alimentaria). The population below this poverty line cannot afford enough food to ensure adequate nutrition. The second poverty line is equivalent to the total value of the food plus non-food basket per person per month and hence refers to a general well-being standard (Bienestar - Canasta alimentaria y no alimentaria). Both poverty lines are useful to calculate since each captures a different magnitude of poverty. Each poverty line is calculated for rural and urban individuals in monthly income per capita values in current prices which allows for a distinction between rural and urban poverty in the calculations. In the analysis, the average of the indicated monthly values over the year 2014 was used. The calculated poverty indices differ quite strongly over rural and urban areas, while the total value is dominated by the large urban population. The poverty headcount using the wellbeing poverty line is 45 percent overall while 54 and 42 percent in rural and urban areas respectively (table 3.3).[10] The Gini coefficient is at a relatively high level of 0.52 in international comparison and lower within urban and rural areas.

Reliability of household survey data, as well as national accounts data, is heavily debated in the literature (Datt and Ravallion, 2011; Deaton, 2005). The usual problem is that household survey data aggregates are considerably smaller than calculated in national account data. With the data used in our analysis, we can confirm the huge spread between consumption in the micro household and in the input-output data. However, information on input-output data specific problems or survey issues such as item underreporting, sample selection issues etc. for Mexico are unavailable to the authors. We assume the IO data to be more reliable and correct the survey data with a general scaling factor representing the relationship between the IO and survey consumption aggregate. For relative welfare measures, this scaling procedure has no effect on results but absolute changes and redistribution effects are different. The consumption aggregate in the IO data for the most recent available year 2011 is 2.7 times greater than in the survey data for the year 2014, although economic growth rates have been around 2.5 percent on average from 2011 to 2014 (World Bank, 2016). If consumption by households grew with the same rate, the survey data covers only 35.5 percent of the IO consumption aggregate resulting in a scaling factor of 2.81.

[10]Differences to poverty statistics published by CONEVAL are due to equivalence scales, which we do not use since our focus is on poverty changes trough different tax rates and not through family composition.

Table 3.3 FGT poverty indices and Gini index (2014)

Poverty line	Index	National	Rural	Urban
Minimum Wellbeing	FGT 0	0.14	0.23	0.11
	FGT 1	0.04	0.08	0.03
	FGT 2	0.02	0.04	0.01
Wellbeing	FGT 0	0.45	0.54	0.42
	FGT 1	0.17	0.23	0.15
	FGT 2	0.08	0.13	0.07
	Gini	0.52	0.45	0.5

3.4 Results

The different carbon tax rates and tax bases generate a wide variety of price changes for households. Reflecting the carbon intensity of the respective production sector, price increases can be expected to rise from Scenario A to C, although with differences in sectors. The carbon intensity for electricity and utilities, calculated by excluding natural gas, jet fuel and non-energy emissions in scenario A (table 3.4), is considerably smaller than in Scenario B (table 3.5). Resulting price changes are small for the current tax rate and moderate for higher tax rates. With a tax of 3.5 USD per ton CO_2, the price change in the electricity sector is well below one percent and rises up to 10 percent with 50 USD per ton. The largest price change in the current tax regime can be expected from refined petroleum products such as gasoline. Including natural gas in the taxation of CO_2 emissions (Scenario B) naturally increases the price for electricity and since the emissions covered increase by almost 100 percent, the carbon intensity and associated price changes with a similar magnitude relative to Scenario A. Electricity price changes now dominate fuel price increases. For other sectors, the inclusion of natural gas slightly increases price changes. As expected, including CH_4 and N_2O in taxation (Scenario C, table 3.6) lead to strong price increases for agricultural products and to a lesser extent for processed food reflected in larger carbon intensities for these sectors. Other sectors are less affected in Scenario C and show carbon intensities and price increases similar to Scenario B. Resulting welfare effects also increase with the coverage of emissions from Scenario A to C and with the tax rate. For the currently implemented tax rate close to 3.5 USD/ t CO_2 the welfare effects are generally slightly progressive and small below 0.2 percent of total expenditures for most households. Welfare effects increase to a maximum of 4.2 percent of total expenditures for the poorest households in Scenario C for a tax rate of 50 USD/t CO_2.

Table 3.4 CO_2 Intensities for final demand and price changes (Scenario A)

		price changes in % for carbon tax rates (in USD)		
Sector No	CI (t/Mio MXN)	3.5	20	50
1	29.07	0.13%	0.72%	1.80%
2	3.57	0.02%	0.09%	0.22%
3	12.50	0.05%	0.31%	0.77%
4	12.75	0.06%	0.32%	0.79%
5	9.06	0.04%	0.22%	0.56%
6	14.06	0.06%	0.35%	0.87%
7	10.45	0.05%	0.26%	0.65%
8	202.26	0.88%	5.01%	12.52%
9	5.24	0.02%	0.13%	0.32%
10	7.20	0.03%	0.18%	0.45%
11	40.40	0.18%	1.00%	2.50%
12	8.79	0.04%	0.22%	0.54%
13	3.40	0.01%	0.08%	0.21%
14	4.67	0.02%	0.12%	0.29%
15	5.21	0.02%	0.13%	0.32%
16	12.85	0.06%	0.32%	0.80%
17	158.43	0.69%	3.92%	9.81%
18	13.04	0.06%	0.32%	0.81%
19	14.19	0.06%	0.35%	0.88%
20	5.54	0.02%	0.14%	0.34%
21	10.15	0.04%	0.25%	0.63%
22	19.43	0.08%	0.48%	1.20%
23	21.24	0.09%	0.53%	1.31%
24	143.45	0.62%	3.55%	8.88%
25	8.69	0.04%	0.22%	0.54%
26	15.97	0.07%	0.40%	0.99%
27	6.41	0.03%	0.16%	0.40%
28	3.01	0.01%	0.07%	0.19%
29	2.29	0.01%	0.06%	0.14%
30	7.08	0.03%	0.18%	0.44%
31	11.06	0.05%	0.27%	0.68%
32	10.37	0.04%	0.26%	0.64%
33	8.07	0.03%	0.20%	0.50%
34	10.18	0.04%	0.25%	0.63%

Table 3.5 CO_2 Intensities for final demand and price changes (Scenario B)

		price changes in % for carbon tax rates (in USD)	
Sector No	CI (t/Mio MXN)	20	50
1	32.52	0.80%	2.00%
2	3.47	0.63%	1.57%
3	12.80	0.41%	1.02%
4	17.49	0.43%	1.07%
5	10.74	0.32%	0.80%
6	17.84	0.45%	1.12%
7	13.17	0.46%	1.15%
8	209.01	5.37%	13.42%
9	7.96	0.34%	0.86%
10	12.35	0.32%	0.79%
11	44.01	1.38%	3.45%
12	12.53	0.51%	1.27%
13	9.07	0.13%	0.33%
14	6.03	0.19%	0.48%
15	6.14	0.20%	0.49%
16	13.03	0.55%	1.38%
17	158.31	7.18%	17.95%
18	12.45	0.44%	1.10%
19	13.87	0.43%	1.07%
20	5.31	0.19%	0.48%
21	9.94	0.30%	0.76%
22	19.40	0.61%	1.52%
23	20.94	0.73%	1.82%
24	143.30	3.63%	9.08%
25	9.83	0.32%	0.79%
26	16.07	0.45%	1.12%
27	6.31	0.20%	0.51%
28	3.03	0.10%	0.24%
29	2.25	0.09%	0.22%
30	7.11	0.22%	0.55%
31	11.43	0.36%	0.91%
32	10.34	0.29%	0.72%
33	7.75	0.27%	0.68%
34	10.32	0.33%	0.83%

Table 3.6 CO_2 Intensities for final demand and price changes (Scenario C)

		price changes in % for carbon tax rates (in USD)	
Sector No	CI (t/Mio MXN)	20	50
1	172.93	4.28%	10.70%
2	31.80	0.79%	1.97%
3	43.72	1.08%	2.71%
4	23.63	0.58%	1.46%
5	19.44	0.48%	1.20%
6	47.12	1.17%	2.92%
7	20.03	0.50%	1.24%
8	222.20	5.50%	13.75%
9	21.57	0.53%	1.33%
10	15.22	0.38%	0.94%
11	100.26	2.48%	6.21%
12	27.79	0.69%	1.72%
13	6.28	0.16%	0.39%
14	9.50	0.24%	0.59%
15	9.58	0.24%	0.59%
16	26.51	0.66%	1.64%
17	296.62	7.34%	18.36%
18	23.27	0.58%	1.44%
19	18.92	0.47%	1.17%
20	9.59	0.24%	0.59%
21	13.95	0.35%	0.86%
22	26.49	0.66%	1.64%
23	31.21	0.77%	1.93%
24	151.90	3.76%	9.40%
25	74.78	1.85%	4.63%
26	19.10	0.47%	1.18%
27	9.23	0.23%	0.57%
28	4.90	0.12%	0.30%
29	3.82	0.09%	0.24%
30	10.06	0.25%	0.62%
31	15.96	0.40%	0.99%
32	12.04	0.30%	0.75%
33	12.83	0.32%	0.79%
34	101.27	2.51%	6.27%

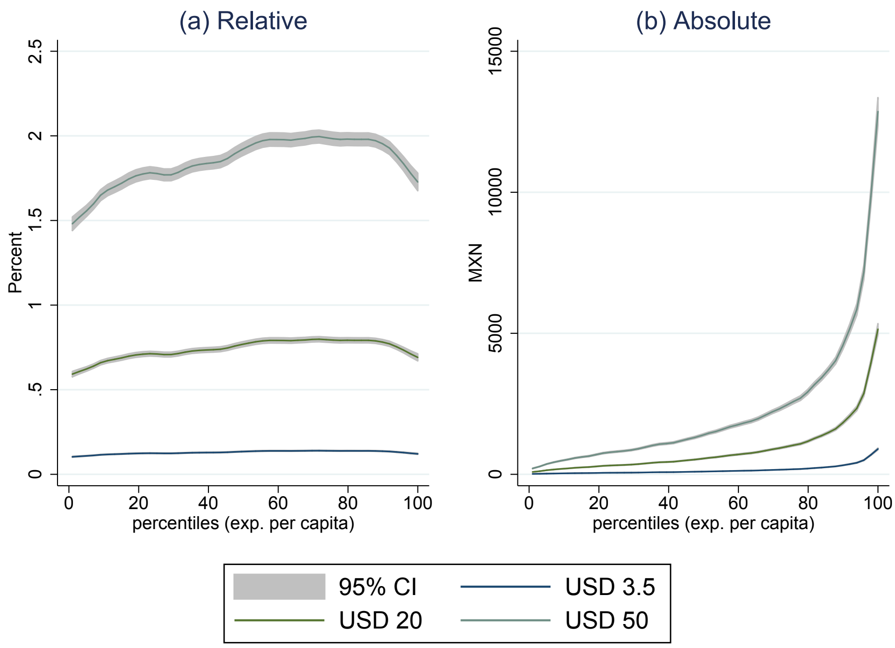

Fig. 3.4 Relative (a) and absolute (b) welfare effects Scenario A

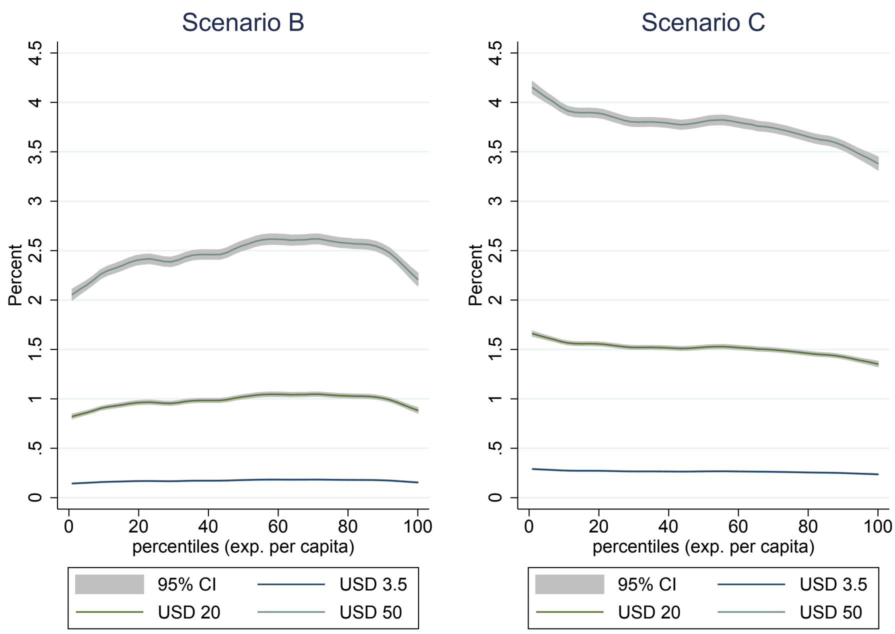

Fig. 3.5 Relative welfare effects scenario A and B

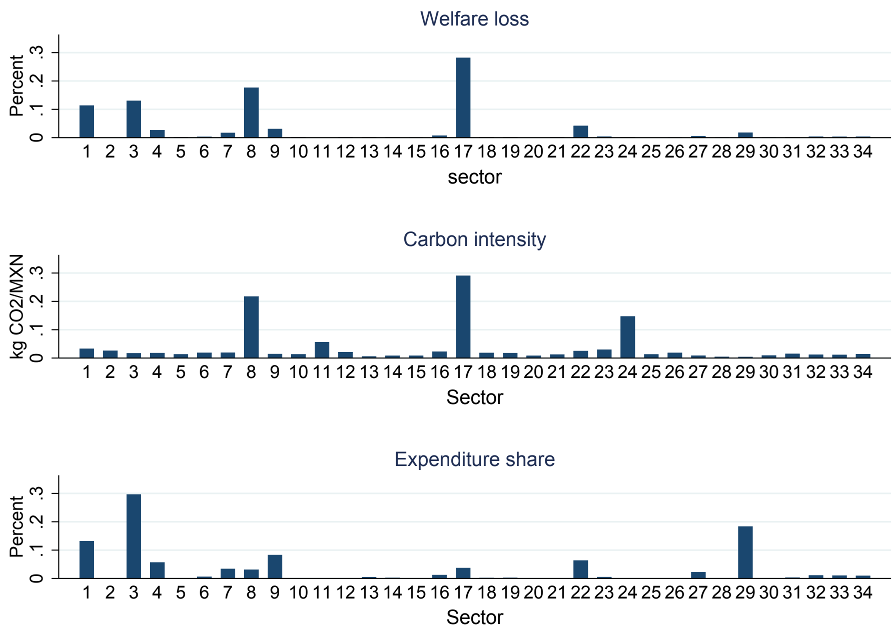

Fig. 3.6 Decomposition welfare loss, bottom 10 percent

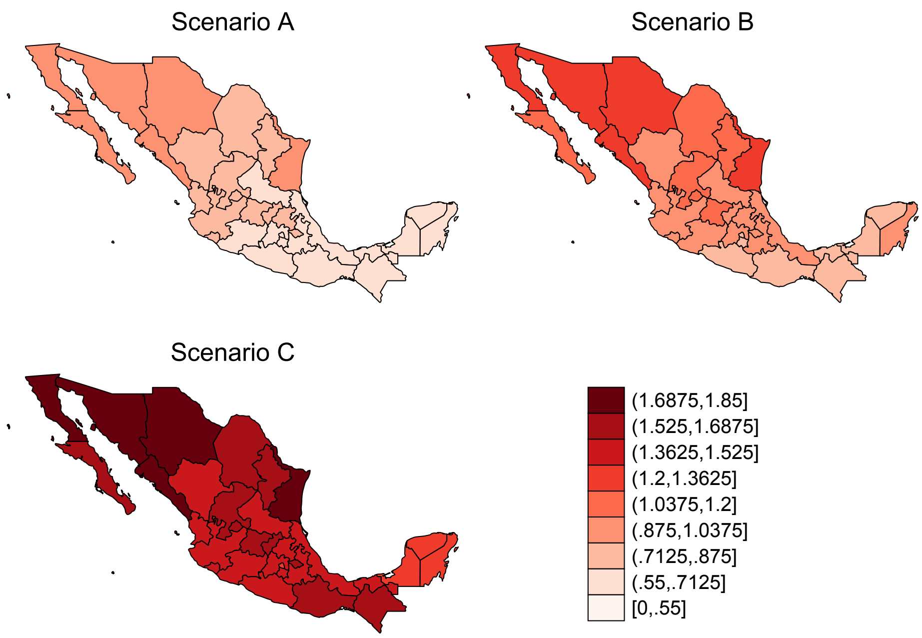

Fig. 3.7 Average relative welfare losses per federal state

For Scenario A, relative welfare losses rise until the 60th percentile, stay constant until the 80th percentile and decline afterwards (figure 3.4). The absolute effect rises along the expenditure distribution as already indicated in the description of the expenditures and the carbon footprint. A more ambitious climate policy with higher tax rates of 20-50 USD/t CO_2 would come with the same relative distributional pattern, although progressivity is more visible. With a larger tax rate of 50 USD/t CO_2, welfare losses are at 1.5 percent for the bottom part of the expenditure distribution. Poverty indices are hardly affected from the lower rates, whereas a 50 USD tax would increase the national minimum wellbeing and wellbeing poverty rates by 0.6 and 0.9 percentage points respectively (table 3.7), mainly driven by gasoline and electricity prices. For both poverty lines, rural poverty increases more than urban poverty.

Table 3.7 FGT poverty indices (in %), changes from baseline (Scenario A)

		Minimum Wellbeing			Wellbeing		
Scenario	FGT	National	Rural	Urban	National	Rural	Urban
I (USD 3.5)	0	0.064	0.000	0.082	0.081	0.024	0.097
	1	0.016	0.024	0.013	0.036	0.042	0.034
	2	0.008	0.015	0.006	0.023	0.030	0.021
II (USD 20)	0	0.307	0.379	0.287	0.369	0.298	0.389
	1	0.090	0.140	0.076	0.205	0.243	0.194
	2	0.047	0.086	0.036	0.133	0.171	0.122
II (USD 20) Lump-Sum	0	-0.336	-0.465	-0.300	-0.228	-0.480	-0.157
	1	-0.138	-0.333	-0.084	-0.214	-0.450	-0.147
	2	-0.081	-0.216	-0.044	-0.165	-0.356	-0.111
II (USD 20) PROSPERA	0	-0.732	-1.975	-0.383	-0.355	-1.960	0.096
	1	-0.387	-1.236	-0.148	-0.476	-1.655	-0.145
	2	-0.233	-0.790	-0.076	-0.408	-1.321	-0.152
III (USD 50)	0	0.616	0.818	0.559	0.918	0.978	0.902
	1	0.231	0.358	0.195	0.519	0.616	0.492
	2	0.123	0.224	0.095	0.338	0.434	0.311
III (USD 50) Lump-Sum	0	-0.703	-1.279	-0.542	-0.580	-1.276	-0.385
	1	-0.334	-0.809	-0.200	-0.526	-1.104	-0.364
	2	-0.193	-0.511	-0.104	-0.402	-0.866	-0.272
III (USD 50) PROSPERA	0	-1.706	-4.942	-0.798	-0.820	-4.583	0.237
	1	-0.806	-2.616	-0.299	-1.082	-3.748	-0.333
	2	-0.439	-1.522	-0.135	-0.876	-2.844	-0.324

Table 3.8 FGT poverty indices (in %), changes from baseline (Scenario B)

		Minimum Wellbeing			Wellbeing		
Scenario	FGT	National	Rural	Urban	National	Rural	Urban
I (USD 3.5)	0	0.085	0.000	0.109	0.148	0.075	0.168
	1	0.021	0.032	0.018	0.048	0.056	0.046
	2	0.011	0.020	0.008	0.031	0.039	0.029
II (USD 20)	0	0.372	0.495	0.338	0.499	0.448	0.513
	1	0.122	0.187	0.104	0.276	0.322	0.263
	2	0.064	0.115	0.050	0.179	0.227	0.166
II (USD 20) Lump-Sum	0	-0.404	-0.683	-0.325	-0.285	-0.729	-0.161
	1	-0.175	-0.429	-0.104	-0.270	-0.579	-0.183
	2	-0.103	-0.276	-0.054	-0.208	-0.458	-0.138
II (USD 20) PROSPERA	0	-0.912	-2.621	-0.432	-0.410	-2.497	0.176
	1	-0.482	-1.555	-0.182	-0.599	-2.106	-0.176
	2	-0.285	-0.975	-0.091	-0.510	-1.666	-0.186
III (USD 50)	0	0.833	1.049	0.773	1.237	1.203	1.246
	1	0.315	0.479	0.269	0.701	0.820	0.668
	2	0.169	0.303	0.132	0.459	0.580	0.425
III (USD 50) Lump-Sum	0	-0.961	-1.700	-0.753	-0.767	-1.693	-0.508
	1	-0.419	-1.031	-0.248	-0.661	-1.416	-0.450
	2	-0.241	-0.644	-0.127	-0.504	-1.106	-0.335
III (USD 50) PROSPERA	0	-2.190	-6.230	-1.056	-1.088	-5.785	0.230
	1	-0.941	-3.101	-0.335	-1.319	-4.638	-0.388
	2	-0.492	-1.743	-0.141	-1.043	-3.439	-0.371

Including natural gas in the taxation of emissions (Scenario B), a 50 USD tax rate increases welfare losses up to 2.1 and 2.6 percent for low and high income households respectively (Figure 3.5). The currently implied tax rate of 3.5 USD would still create small welfare losses below 0.2 percent of total expenditures for all households. The maximum wellbeing poverty rate increase is 1.2 percentage points with a 50 USD tax (table 3.8). In this scenario, extremely poor rural households are hit worse than their urban counterparts. At the wellbeing poverty line, differences between urban and rural poverty impacts are less pronounced.

The story changes essentially with the inclusion of CH_4 and N_2O in the taxation of emissions (Scenario C). The price increase for agricultural and processed food products not just leads to higher welfare losses it also increases regressivity since poorer households spend relatively more on food products (figure 3.5). This is reflected in an increase in the minimum wellbeing poverty rate on the national level of 1.5 percentage points for a 50 USD

Table 3.9 FGT poverty indices (in %), changes from baseline (Scenario C)

		Minimum Wellbeing			Wellbeing		
Scenario	FGT	National	Rural	Urban	National	Rural	Urban
I (USD 3.5)	0	0.131	0.178	0.118	0.169	0.080	0.194
	1	0.037	0.065	0.030	0.078	0.103	0.071
	2	0.020	0.042	0.014	0.052	0.076	0.046
II (USD 20)	0	0.557	0.880	0.466	0.770	0.795	0.763
	1	0.219	0.382	0.173	0.452	0.596	0.411
	2	0.120	0.246	0.084	0.305	0.441	0.266
II (USD 20) Lump-Sum	0	-0.523	-0.773	-0.452	-0.444	-1.035	-0.278
	1	-0.229	-0.546	-0.140	-0.369	-0.759	-0.260
	2	-0.132	-0.344	-0.073	-0.279	-0.590	-0.191
II (USD 20) PROSPERA	0	-1.333	-3.684	-0.673	-0.567	-3.494	0.255
	1	-0.644	-2.098	-0.236	-0.834	-2.940	-0.243
	2	-0.364	-1.262	-0.112	-0.690	-2.270	-0.247
III (USD 50)	0	1.489	2.111	1.315	1.750	1.652	1.778
	1	0.573	0.996	0.454	1.154	1.520	1.052
	2	0.322	0.658	0.228	0.786	1.140	0.687
III (USD 50) Lump-Sum	0	-1.319	-2.388	-1.019	-1.072	-2.037	-0.800
	1	-0.535	-1.281	-0.326	-0.898	-1.839	-0.634
	2	-0.302	-0.783	-0.167	-0.666	-1.403	-0.460
III (USD 50) PROSPERA	0	-2.723	-8.246	-1.172	-1.547	-8.292	0.346
	1	-1.083	-3.723	-0.342	-1.701	-6.078	-0.472
	2	-0.518	-1.943	-0.119	-1.273	-4.302	-0.424

tax (table 3.9). More pronounced than in scenarios where only energy related emissions are taxed, is also the increase of poverty intensity and severity. With large food price changes, households above the poverty line will fall below the poverty line but also households below the poverty line face increasing difficulties to escape poverty. This holds particularly for rural households, which are already severely affected by price increases for energy items.

Reflecting the large rural urban income gap and despite the smaller poverty impacts, urban households face slightly higher welfare losses than rural households in scenario A and B when only energy emissions are taxed. Urban households spend relatively more on direct energy goods such as electricity. In Scenario C, rural low income households face higher welfare losses than their urban counterparts. For most socioeconomic groups, welfare effects lie within a 95 percent confidence interval of the average percentile consumption and are thus mostly statistically insignificant over the income distribution for all scenarios. We do not find any significant difference in welfare effects between female and male headed households and small differences due to family sizes. Age plays some role for consumption decisions, households with older household heads suffer slightly higher welfare losses. This finding can be explained by relatively higher expenditures for emission intensive utilities compared to households with younger household heads.

To understand the role of the single sectors in shaping welfare effects, we provide a graphical overview of sector specific carbon intensities, welfare effects and household expenditure shares for a USD 20 tax rate on CO_2 emissions from energy use (Scenario B). For the bottom 10 percent of the expenditure distribution, agricultural products, processed food, refined petroleum and utilities make up the largest part of the welfare loss (figure 3.6). Agricultural products are not very energy intensive but households spend a large share of their income on processed foods. The carbon intensity for the utilities and refined petroleum products are the highest, which make them main contributors for the welfare loss despite a relatively low expenditure share. Expenditure patterns are different for the top 10 percent of the expenditure distribution, who spend relatively more on rent and service oriented goods such as hotels and restaurants (figure 3.6, appendix) but also on refined petroleum products such as gasoline. The latter becomes the consumption item causing the largest welfare loss and the main driver behind the progressive distributional effect in taxing CO_2 emission from energy use.

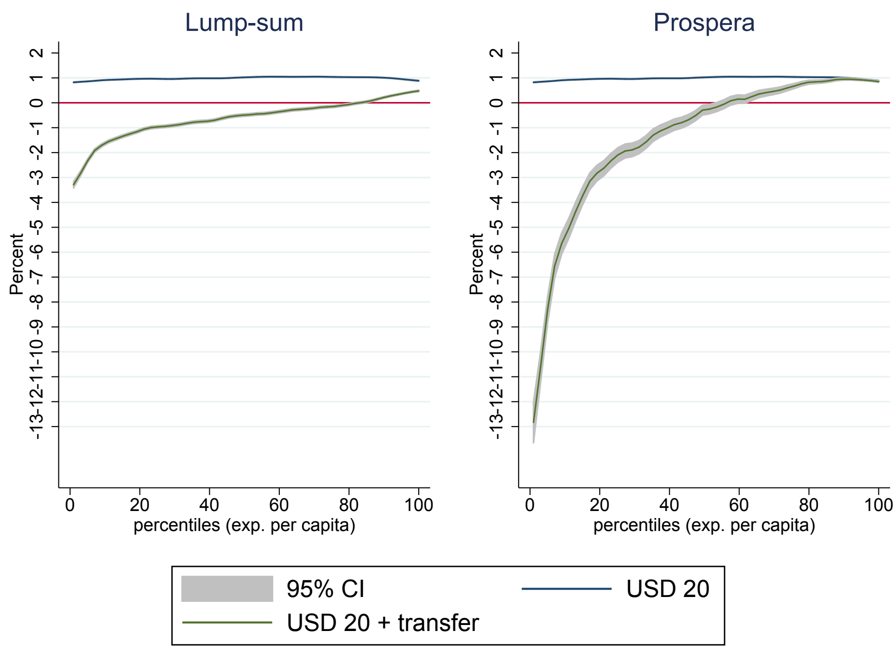

Fig. 3.8 Welfare effects lump-sum vs. PROSPERA redistribution Scenario B

Additionally to finding differences in welfare effects across the expenditure distribution with different tax scenarios, we find spatial heterogeneity within the country. In line with our findings over the expenditure distribution, northern states, which generally exhibit above average expenditures per capita have higher average welfare losses in scenarios covering energy emissions only (Figure 3.7).
The reason can be found in higher budget shares for electricity and fuels in northern states. With CH_4 and N_2O emissions included, this spatial heterogeneity mostly vanishes since associated food price increases particularly lead to large welfare losses in southern states.

Finally, a redistribution simulation of projected tax revenues for our three scenarios is an elementary part for the analysis of distributional effects. Transferring total tax revenues in a lump-sum fashion per household in Scenario B with a 20 USD tax results in average welfare gains for the bottom 85 percent of the distribution (figure 3.8). Welfare gains for households at the lower end of the distribution are large with a magnitude of up to three times the effect of the counterfactual welfare loss. This large redistribution effect occurs despite the fact that low income households benefit less from the redistribution than high income households on a per capita basis due to larger family sizes. Poverty indicators decrease across all dimensions but more so for rural areas, where the combined tax and lump-sum redistribution scheme would lead to poverty rate declines of about half a percentage point at both poverty lines. Redistribution of full tax revenues via PROSPERA has the potential to generate huge welfare gains for PROSPERA recipients more than 10 percent of total household expenditures. Surprisingly, a nonsignificant share of households above the median income benefit from PROSPERA although they are not classified as poor. Poverty reductions are much stronger in this case, particularly at the minimum wellbeing poverty line and for rural households (table 3.8.

In all other simulated scenarios with redistribution, distributional patterns become even more progressive with higher tax revenues, particularly for PROSPERA scenarios. The urban poverty rate on the other hand remains either constant or increases slightly in all PROSPERA scenarios, which leads to moderate national poverty reductions despite massive improvements for rural households. Two reasons are behind this finding. First, PROSPERA is mainly targeted at very poor, particularly rural households. Urban households close to the wellbeing poverty line are less likely to be recipients of PROSPERA. Second, the urban wellbeing poverty line is significantly larger than the rural poverty line. Generally all redistribution simulations clearly reverse the regressive into a progressive overall effect.

Inequality indices such as the Gini Index hardly react to the magnitude of welfare effects caused by the different tax rates in our analysis (table B.1). The distributional effects of carbon taxes are not severe enough to create significant changes in the income distribution on the national level, not even with high tax rates and a broad tax base. However, redistribution of tax revenues via targeted cash transfer programs can decrease income inequality within rural areas or keep it constant when smaller shares of tax revenues are used for redistribution. If the tax is accompanied with border tax adjustments makes no significant difference, welfare effects remain largely unaffected. Although 9.5 percent of consumption goods get imported, these are mainly goods from less carbon intensive sectors such as the processed food and transport equipment sectors.

3.5 Conclusion

Our analysis offers a detailed view on potential welfare effects of different carbon tax scenarios for Mexico. The current rate of the carbon tax is small enough not to create much impact for household welfare. Although we are not able to calculate resulting emission reductions, the current effect can expected to be negligible with the currently implemented tax regime. Adding to it, natural gas remains tax exempt and makes up 25 percent of energy related CO_2 emissions which renders the policy partly inefficient. As we show, including natural gas increases the welfare losses due to higher electricity prices. Although the inclusion of aviation fuels in the carbon tax would naturally increase efficiency, these effects are negligible since jet fuel emissions are only 2 percent of total energy related emissions. To have a measurable effect on national CO_2 emissions, the necessary higher tax rates are projected to have negative effects on household welfare and related poverty outcomes. The exact magnitude and distributional outcome indeed depends on the tax rate but also on the share of taxed emissions. In the case of the highest simulated tax rate of 50 USD/tCO_2e and including CH_4 and N_2O in the taxation, we find overall effects to be regressive with relative welfare losses at 4.2 and 3.4 percent of total expenditures for the poorest and richest households respectively. For carbon tax rates of 20 USD/tCO_2 exclusively taxing CO_2 from energy use, which might be more realistically expected in climate policies, welfare losses are progressive and around 1 percent of total expenditures for all households. Naturally, the reason for this progressivity is a rising carbon intensity of consumption over the expenditure distribution up to a certain income level, driven by transport fuels such as gasoline. In contrast, the top decile demands more service oriented, low carbon intensive goods which lessens the progressivity of carbon taxes to some extent. Nevertheless, absolute tax payments strictly rise with income. Although welfare effects are generally moderate for low tax rates, total tax revenues allow for relatively high transfers to low income households which render the policy clearly progressive. National poverty incidence is more sensitive at the wellbeing poverty line in scenarios covering only energy related CO_2 emissions. Additionally, low income rural households are also at higher risk than their urban counterparts. In the case of food price increases through taxation of CH_4 and N_2O, poverty is much stronger affected which demonstrates the importantance of a well thought through redistribution mechanism. Nevertheless, since distributional results are calculated on average per expenditure percentile, they hide an important fact. In scenarios with redistribution not every poor household benefits through the PROSPERA system. The share of PROSPERA recipients in the lowest percentile is about 70 percent and declines to 13 percent at the 50th percentile, resulting in a substantial number of households below the minimum wellbeing and other households close to the bienestar poverty line not covered, particularly in urban areas. Despite the on average promising redistribution outcome, targeting must be improved to achieve poverty reductions for the entire population.

Chapter 4

Household Welfare and CO_2 Emission Impacts of Energy and Carbon Taxes in Mexico

4.1 Introduction

Mexico has become a major emitter of greenhouse gas emissions over the last decades with both economic and population growth as driving forces. In response, the Mexican government committed itself to carbon dioxide emission reductions relative to a baseline scenario and passed a climate change law in 2012 with legally binding emission reduction goals (Vance, 2012). Additionally, substantial reform efforts in the energy sector have been made recently that may affect energy prices. The oil and gas industry was opened to competition in the up-, middle- and downstream sectors and Mexican households will be subjected to international gasoline prices by 2018. The Federal Electricity Commission (CFE) is planned to be reformed with the objective to form and regulate a competitive electricity market with incentives for private investment (The Atlantic Council, 2014). In the residential electricity market, large seasonal subsidies in warmer regions of Mexico continue to exist to cover for higher demand of air conditioning (Davis et al., 2014; Komives et al., 2009). While the effects of these (potential) reforms on energy consumer prices are uncertain in some cases (oil sector) or modest in others (gasoline price subsidies), ambitious climate policy implies increasing energy prices in a country with a fossil-fuel reliant energy system. Higher energy prices are thus likely to lead to welfare losses in the short-run that may not be equally distributed. In developed countries, poorer households tend to be more vulnerable to energy price increases, as energy goods usually represent a larger proportion of their total expenditure with some exceptions for transport fuels (Flues and Thomas, 2015; Speck, 1999). For developing countries, although there is less evidence on the distributional effects, it has been pointed out early by Shah and Whalley (1991) as well as Shah and Larsen (1992) that emerging distributional patterns are supposedly different. The recently growing literature on welfare effects of energy price changes or subsidy reform mainly focuses on fuel prices with some emphasis on gasoline. Various countries are covered in the volume of Sterner (2011) and in Arze del Granado et al. (2012). A general result is that high-income households capture significantly higher amounts of subsidies for fuels than low income households. A similar result is found by Datta (2010), who investigates the distributional welfare effects of a fuel tax in India. Gillingham et al. (2006) show that the direct (consumption losses via higher prices) and indirect (income effects) welfare impacts of fuel price increases (both domestic and transport fuels) are either regressive or distributional neutral in relative terms for a range of developing countries. Potentially large welfare losses due to higher energy prices are particularly critical for middle income countries with relatively high CO_2 emissions and the need for further economic development, growth, and poverty reduction. Mexico is such a case where nearly half of the population still lives below the official poverty line (Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL, 2014)). Against this background, the present study adds to the literature in two ways. First, we provide some evidence on the short-run poverty and distributional effects of energy price changes for Mexico. We calculate the welfare impacts of hypothetical price increases of electricity, motor fuels, gas and public transportation. Since these price changes can be interpreted as environmental taxes, we can also assess how tax revenues can be redistributed, for example by employing cash-transfers to households. Additional to price changes for energy items, we simulate the welfare impacts of scaling up the carbon tax that was initially introduced in 2014. By drawing on the demand estimates, we examine whether second-order effects need to be calculated for the welfare analysis in our context. By estimating a censored consumer demand system, we incorporate the discrete choice to use certain energy types and the exact pattern of substitution between them and other goods. Second, we calculate the short-run CO_2 emission savings potential of consumer responses due to energy and carbon taxes. The rest of the paper proceeds as follows. First, we present the database on which the analysis is based upon with some descriptive statistics in section 4.2. In section 4.3 we describe the theory and the closely connected empirical strategy to measure welfare effects and household induced CO_2 emissions. We present the results in section 4.4, conclude in section 4.5 and provide some policy recommendations.

4.2 Household energy use

We use household expenditure data from ENIGH surveys conducted by INEGI, the national institute for geography and statistics in Mexico. The data are representative at both the national level as well as rural and urban areas. They contain information on item-wise expenditure for every household, as well as an extensive list of variables capturing household and sociodemographic characteristics. The expenditure categories used in the analysis are (1) electricity, (2) motor fuels (including low-/ and high-octane gasoline as well as diesel and gas), (3) gas (aggregate of natural gas and LPG), (4) public transportation, (5) food (excluding alcohol and tobacco) and (6) other goods. Figure 4.1 shows the distribution of energy expenditures over expenditure percentiles for 2014.[1] Expenditures on the four energy goods relative to total expenditures range between 6 and 13 percent of total household expenditures. A clear reverse U-shaped curve can be observed for total energy budget shares over the total expenditure distribution.

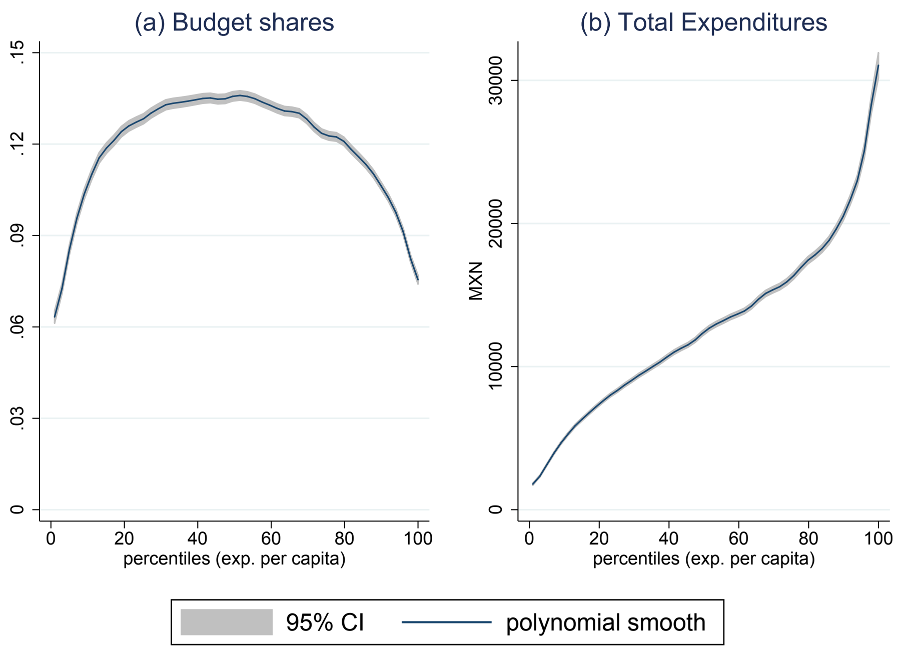

Fig. 4.1 Energy expenditures

Figure 4.2 plots the distributional incidence for the energy goods separately and also distinguishes between users and non-users. This distinction may matter for welfare analyses, as users of some energy good may not find it so easy to switch away from using it. Households

[1] Nonparametric distributional curves are calculated with kernel-weighted local polynomial smoothing using an epanechnikov kernel function with degree 0 and bandwith 1.15.

may own vehicles and other energy-processing durables that they do not want to (or cannot) put out of use. When considering all observations, the electricity consumption share is continuously decreasing over the expenditure distribution, but is exhibiting little variation across percentiles and lies at around 2.4 percent for the poorest households. The slightly declining budget shares over the income distribution pattern are not universally found in other countries, e.g. in Sri Lanka, Mali and Indonesia, richer households exhibit larger electricity budget shares (Gillingham et al., 2006) which is partly a result of the design of electricity tariffs.[2] For motor fuels, the share is rising over the expenditure distribution, ranging from about 1.6 percent to 4.3 percent. Both gas and public transport exhibit an inverse U-shaped curve over the expenditure distribution, with gas being the least important energy good.

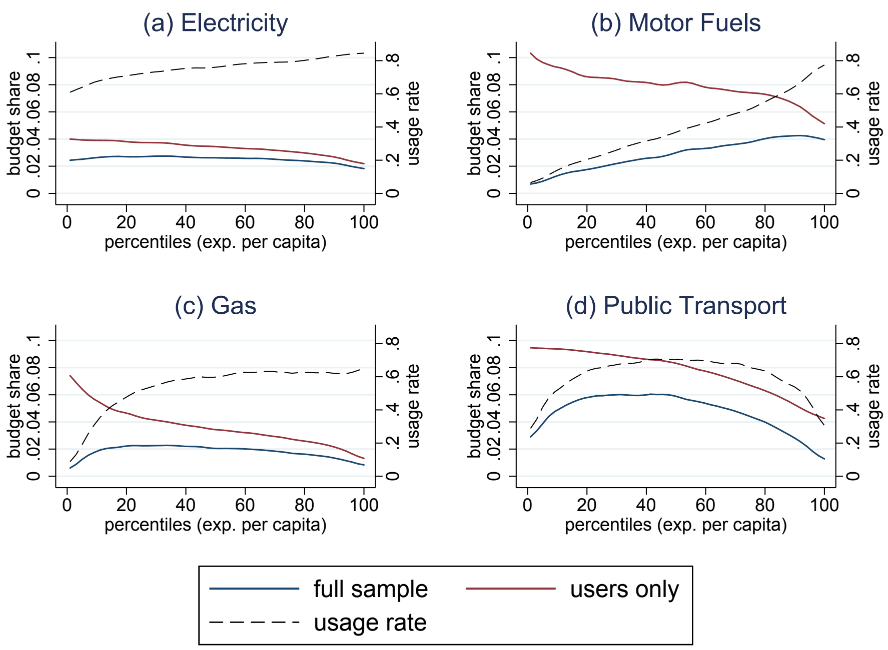

Fig. 4.2 Energy budget shares and usage rates

When only considering households with positive expenditures for the respective energy goods, budget shares continuously decrease with income for all energy types. The difference between user and non-users is most pronounced for motor fuel expenditures for the first decile, for which the mean share is just above 10 percent. Note that only around 16 percent of the households in the poorest decile own a vehicle compared to 73 percent in the richest decile. Poor households that use gas also have a larger expenditure share than rich ones. Public transport expenditure shares for users reach nearly 10 percent for the first deciles and decline

[2]Results for Indonesia can be found in chapter 5.

over the expenditure distribution. Only minor differences in electricity expenditure shares are detected. These findings indicate that the distributional incidence of relative expenditures depend heavily on the usage rate in the respective income groups. Poor households that depend on one of these energy goods might be disproportionately vulnerable when subjected to energy price increases. Our data indicate that motor fuel usage, i.e. the percentage of households consuming some motor fuel, increased from 4.5 percent in the poorest decile to 16 percent between 2002 and 2014. Poor households have thus become more vulnerable to motor fuel price increases. We find that rural households spend slightly less of their current income on electricity than urban households. For the other energy goods, the data shows no significant difference in consumption patterns between rural and urban households (results not reported).

4.3 Methodology

4.3.1 Demand system

We model the demand for electricity, motor fuels, gas, public transport, food and other non-durables based on household survey data with a microeconomic, partial equilibrium demand framework. For our analysis we use the Quadratic Almost Ideal Demand System (QUAIDS) framework (Banks et al., 1997) since observed Engel curves appear to be well approximated by a quadratic relationship between budget shares and logarithmic transformed expenditures.[3] The estimation of a QUAIDS has been applied to the energy context by Brännlund and Nordström (2004) and Labandeira et al. (2006) for Sweden and Spain, but according to our knowledge, no demand system specification of this form has been applied to the energy context in low and middle income countries before.[4]

The QUAIDS as a rank three quadratic logarithmic budget share system has an indirect utility function of the following form:

$$\ln V = \left\{ \left[\frac{\ln x - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1} \tag{4.1}$$

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

[3]For higher observed nonlinearity, other systems such as the EASI from Lewbel and Pendakur (2009) would be more appropriate

[4]The Almost Ideal Demand System (AIDS) has been used in related contexts (Symons et al., 1994; West and Williams III, 2004)

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \tag{4.2}$$

$$b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \tag{4.3}$$

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

$$\lambda(p) = \sum_{i=1}^{n} \lambda_i \ln p_i \tag{4.4}$$

with $\sum_i \lambda_i = 0$ the derived expenditure share system is:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \left[\frac{x}{a(p)}\right] + \frac{\lambda_i}{b(p)} \left\{ \ln \left[\frac{x}{a(p)}\right] \right\}^2 \tag{4.5}$$

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

Adding-up

$$\sum_{i=1}^{n} \alpha_i = 1; \quad \sum_{i=1}^{n} \gamma_{ij} = 0; \quad \sum_{i=1}^{n} \beta_i = 0; \quad \sum_{i=1}^{n} \lambda_i = 0 \tag{4.6}$$

Homogeneity

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \tag{4.7}$$

Symmetry

$$\gamma_{ij} = \gamma_{ji} \tag{4.8}$$

Budget elasticities can be derived from the share equation:

$$e_i = \frac{\mu_i}{w_i} + 1 \tag{4.9}$$

with

$$\mu_i = \frac{\partial w_i}{\partial \ln x} = \beta_i + \frac{2\lambda_i}{b(p)} \left\{ \ln \left[\frac{x}{a(p)}\right] \right\} \tag{4.10}$$

The uncompensated price elasticity is given by:

$$e_{ij}^{u} = \frac{\mu_{ij}}{w_i} - \delta_{ij} \tag{4.11}$$

with

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_i} = \gamma_{ij} - \mu_i \left(\alpha_j + \sum_{k}^{n} \gamma_{jk} \ln p_k \right) - \frac{\lambda_i \beta_j}{b(p)} \left\{ \ln \left[\frac{x}{a(p)} \right] \right\}^2 \tag{4.12}$$

and δ_{ij} is the Kronecker delta. Compensated price elasticities are derived by the slutsky equation

$$e_{ij}^{c} = e_{ij}^{u} + e_i w_j \tag{4.13}$$

Demographic demand shifters including sex, age, education of the household head, household size and a rural area dummy influence preferences through α_i in equation 4.5. To account for zero expenditures, we follow Shonkwiler and Yen (1999) and obtain elasticity estimates in a censored system setting. In first step, a household specific probit model is estimated with the outcome of 1 if the household consumes good i and 0 otherwise. For each household in the sample, the standard normal probability density function (pdf) $\varphi(z_{ih}, w_i)$ and the cumulative distribution function (cdf) $\Phi(z_{ih}, w_i)$ are calculated by regressing w_i on a set of independent variables z_{ih}. In a second step, the pdf and the cdf are integrated into the system of equations:

$$w_i^* = \Phi w_i + \varphi_i \phi \tag{4.14}$$

Opposed to Heckman (1979), this approach is based on the full sample in both steps of the estimation process. The elasticities change as:

Expenditure elasticity

$$e_i^* = \frac{\Phi(\mu_i)}{w_i} + 1 \tag{4.15}$$

Price elasticity

$$e_{ij}^* = \frac{\Phi(\mu_i)}{w_i} + \phi \tau_{ij} (1 - \frac{\varphi_i}{w_i}) - \delta_{ij} \tag{4.16}$$

Since we use prices as dependent variables in the first stage estimation, τ_{ij} is the coefficient of price j from equation i from the probit model. The respective expenditure and price elasticities, e_i and e_{ij} are derived under the modified system (4.14). Explanatory variables used in the probit estimation are listed in table 4.2. This two-step methodology has been extensively applied in agricultural demand contexts (see for example Ecker and Qaim (2011);

Shonkwiler and Yen (1999); Yen et al. (2002)) but not yet for energy demand. The censored system is estimated for the full system and therefore loses the adding-up restriction, which is why we calculate approximate second-order welfare effects based on equation (20). We use a two-step feasible generalized nonlinear least squares (FGNLS) estimator for the estimation of equation (17). Identification of price elasticities is enabled through cross-sectional (spatial) and time variation. We select eight years for the demand system estimation: 2002, 2004, 2005, 2006, 2008, 2010, 2012 and 2014. Additional to this considerable variation in time, spatial variation comes from CPI data on the city level. The price data consist of indices that are available from INEGI for 46 cities throughout Mexico and every state is represented by at least one city. Households not residing in one of the 46 cities are assigned to the city that is located in their state. When more than one city lies in the respective state, an unweighted average of the price indices is calculated. The price indices are disaggregated for the categories food, gasoline, electricity, gas (aggregated index for both LPG and natural gas) and public transport (inter alia). For other goods, we use the general price index. For motor fuels, we use the aggregated index of low- and high-octane gasoline. To correct for city specific effects, we incorporate city fixed effects in the α_i term in equation 4.5.

4.3.2 Simulation and welfare effects

We simulate price changes for different scenarios, where the price change per good i is simply:

$$\frac{\Delta p_i}{p_i^0} = \frac{p_i^1 - p_i^0}{p_i^0} \tag{4.17}$$

and the new price level after the tax change is:

$$p_i^1 = \left(1 + \frac{\Delta p_i}{p_i^0}\right) p_i^0 \tag{4.18}$$

$\ln a(p)$ and $b(p)$ (equation 4.14) get adjusted accordingly with new price levels and we obtain simulated budget shares for good i and each household according to:

$$\begin{aligned} w_i^1 = \Phi \left(\widehat{\alpha}_i + \sum_{j=1}^{n} \widehat{\gamma_{ij}} \ln p_j^1 + \widehat{\beta}_i \ln \left[\frac{x^0}{a(p^1)} \right] + \frac{\widehat{\lambda}_i}{b(p^1)} \left\{ \ln \left[\frac{x^0}{a(p^1)} \right] \right\}^2 \right) \\ + \varphi_i \phi + \widehat{\varepsilon}_i^0 \end{aligned} \tag{4.19}$$

The “hats” are estimated coefficients from equation 4.14 and the superscripts denote the periods of reference. Household characteristics in the α term remain unchanged in all scenarios. Since the demand system does not predict household expenditures perfectly, the redidual term ε_i containing household specific unexplained effects is included.[5]

The literature on the welfare impacts of energy price increases and subsidy reforms focuses to a large extent on first-order effects as in Sterner (2011). These first-order effects, based on work of Feldstein (1972) and Stern (1987) only require the observed demand and no additional information on substitution behavior due to price changes. First order welfare losses relative to income (total expenditures are used as a proxy) are calculated as:

$$FO = \sum_{i=1}^{n} w_i \left(\frac{\Delta p_i}{p_i^0} \right) \tag{4.20}$$

With estimated coefficients at hand, we calculate a second-order approximation to the Compensating Variation (CV), which is the amount of money the household needs to be compensated with to attain the utility level u^0 prior to the price changes, again relative to total household expenditures:[6]

$$CV = \sum_{i=1}^{n} w_i \left(\frac{\Delta p_i}{p_i^0} \right) + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} w_i e_{ij} \left(\frac{\Delta p_i}{p_i^0} \right) \left(\frac{\Delta p_j}{p_j^0} \right) \tag{4.21}$$

The CV is compared to the first-order effect to clarify the necessity of estimating a demand system in our context. The price change in equation (4.17) can also be interpreted as an ad valorem tax rate t_i. Tax payments per household are then calculated as:

$$T = \sum_{i=1}^{n} \frac{\Delta p_i}{p_i^0} (p_i^0 * q_i^1) = \sum_{i=1}^{n} t_i \frac{exp_i^1}{1 + \frac{\Delta p_i}{p_i^0}} \tag{4.22}$$

which are multiplied with household weights and summed over all households to obtain the total tax revenue. With household substitution already incorporated, simulated expenditures based on equation 4.19 are used for the tax calculation and deflated to the base period. When tax revenues are redistributed to households in the form of direct cash transfers, we assume

[5] Additionally, with the missing adding up restriction, budget shares do not sum perfectly to 1. We find this error to be very small in the range of 0.03 – 0.3 percentage point deviation from 1 in our simulations

[6] The approximation is based on a second-order Taylor series expansion of the expenditure function (Banks et al., 1996; Deaton and Muellbauer, 1980b; Friedman and Levinsohn, 2002)

the additional income is completely spent on non-durable consumption and the new budget shares are:

$$w_i^{1,tr} = \Phi\left(\widehat{\alpha_i} + \sum_{j=1}^{n}\widehat{\gamma_{ij}}\ln p_j^1 + \widehat{\beta_i}\ln\left[\frac{x^1}{a(p^1)}\right] + \frac{\widehat{\lambda_i}}{b(p^1)}\left\{\ln\left[\frac{x^1}{a(p^1)}\right]\right\}^2\right) + \varphi_i\phi + \widehat{\varepsilon_i}^0 \tag{4.23}$$

4.3.3 CO_2 emissions

In our analytical framework, CO_2 emissions (C) are calculated from a demand side perspective. The carbon content of the goods in our analysis may come from three different sources. First, fuels have a direct CO_2 content per physical unit (C_{dir}).[7] Second, goods are produced with energy which leads to the emission of CO_2, the direct production emissions. Third, other goods used in the production process are responsible for the indirect production emissions. We term production emissions from direct and indirect energy use as indirect emissions C_{ind}. Total emissions C are simply the sum of direct and indirect emissions:

$$C = C_{dir} + C_{ind} \tag{4.24}$$

Where applicable, as in the case of fuels, C_{dir} can be calculated based on the expenditure data. The indirect emissions C_{ind} are calculated with an environmentally extended input-output model based on data from the World Input-Output Database (Timmer et al., 2015) as:

$$C_{ind} = CI'x = CI'(I-A)^{-1}y \tag{4.25}$$

where CI is the direct carbon intensity of production, $(I-A)^{-1}$ the Leontief inverse and $CI'(I-A)^{-1}$ the indirect carbon intensities containing all direct and indirect production emissions.[8] These CO_2 emissions embedded in household consumption, the carbon footprints,

[7]For motor fuels we assume the CO_2 content of gasoline: 2.31 kg CO_2/. Gas/LPG: 1.5 kg CO_2/kg. These physical units are transformed to CO_2 intensities per monetary unit by assuming prices of MXN 13 per l motor fuel and MXN 13 per kg of gas. Although this procedure is not precise due to different prices for households over space and fuel choice, it corrects for the otherwise missing direct carbon content on consumption in the absence of quantity information

[8]For details on the calculation of carbon intensities and matching with household expenditures for Mexico, see chapter 3. How we matched the 34 sector production classification to our 6 good demand classification is described in table C.1

are derived by multiplying expenditures per good with the respective carbon intensity CI_k (tCO_2/MXN):

$$CO_2^0 = \sum_{i=1}^{n} (exp_i^0 * CI_i) \tag{4.26}$$

In each scenario, new expenditure levels exp_i^1 per good i and each household are derived from new budget shares w_i^1. New carbon emissions are then calculated as:

$$CO_2^1 = \sum_{i=1}^{n} \left(\frac{exp_i^1}{1 + \frac{\Delta p_i}{p_i^0}} * CI_i \right) \tag{4.27}$$

For the calculation of tax revenue, the simulated expenditures are real expenditures at base prices. They isolate the unobserved quantity effect from the nominal expenditure change. Aggregating over households by using household weights, we obtain total carbon emissions resulting from domestic household demand. The difference to the baseline value is then exclusively explained by consumer substitution. Substitution effects are also taken into account in redistribution scenarios when total expenditures increase through cash transfers. New expenditure levels $exp_i^{1,tr}$ based on equation 4.23 are expected to be higher with normal goods and reduce the emission saving potential determined by the size of β and λ through the budget elasticity.

4.4 Poverty, welfare and CO_2 emissions

In order to understand the implications of energy price changes for household welfare and carbon footprints, we simulate stylized scenarios with price changes for each fuel separately and one scenario with price changes for all energy types simultaneously. In a second step, we take a closer look at potential future policy interventions in the form of different carbon tax rates. Along the way, we check upon the importance of calculating second-order effects for welfare analysis in this context. For the effects on poverty, we calculate absolute welfare effects and subtract them from household income, since domestic poverty lines are constructed with household income per capita (CONEVAL, 2014). We calculate FGT poverty indices on the basis of poverty lines for Mexico provided by the National Council for the Evaluation of Social Development Policy CONEVAL (Consejo Nacional de Evaluacion de la Politica de Desarrollo Social). CONEVAL indicates two different poverty lines. One refers to extreme poverty illustrated by the minimum wellbeing standard of an individual which corresponds to the value of the food basket per person per month (Bienestar minimo -

Canasta alimentaria). The population below this poverty line cannot aquire enough food to ensure adequate nutrition. The second poverty line is equivalent to the total value of the food plus non-food basket per person per month and hence refers to a general wellbeing standard (Bienestar - Canasta alimentaria y no alimentaria). We provide results for both poverty lines to distinguish between effects on extreme and moderate poverty.

4.4.1 Energy price changes

Since the direct interpretation of the coefficients is difficult, we report elasticities in table 4.1. Following Banks et al. (1997), we calculate elasticities for each household individually and construct a weighted average, with the weights generated as the household's share of total sample expenditure for the relevant good. The estimated budget elasticities suggest that on average, households perceive motor fuels as a luxury good and electricity, gas and public transport as necessities. For the latter three energy items, income elasticities are fairly close to 1 which indicates quickly rising energy demand with income growth. Income plays a more nuanced role for the discrete energy use decision. With a very high electrification rate, income is no important determinant for using electricity at all. In the case of motor fuel, income plays a major role for the determination of private transport vehicle ownership. The probability of public transport use on the other hand is only slightly affected by rising incomes but more so by the necessity and convenience of this transportation mode, reflected in a large effect of the rural dummy.

Uncompensated own-price elasticities all show the expected negative signs and reflect inelastic household responses to price changes with the exception of electricity and motor fuels. Cross-price elasticities between energy items show the expected pattern, e.g. the domestically used electricity and gas and transport expenditures motor fuel and public transport are substitutes although fairly inelastic. Compensated price elasticities for energy items, used in the calculation of welfare effects, do not differ significantly since expenditure elasticities are all close to 1. For food and other goods, the elasticities become indistinguishable from 0. Based on the observance of energy price elasticities, we would not expect large differences between the first- and second-order welfare effects except for electricity price changes.

The descriptive analysis of budget shares has already revealed the potential distributional patterns of price changes for the respective energy types. Reflecting these expenditure patterns, the magnitude of a stylized price change of 20 percent per energy good separately is displayed in figure 4.3. We find almost no difference between first- and second-order welfare losses. Overall, the calculated own-price elasticities imply a smaller second- relative to the first-order effect on average. However, the use of 95 percent confidence intervals in the calculation of average welfare effects per percentile reveals no statistically signifi-

Table 4.1 Demand elasticities

Uncompensated Price Elasticities

		Price					
		Electricity	Motor fuels	Gas	Publ Trans	Food	Other
Demand	Electricity	-1.49	-0.16	0.14	0.03	0.03	0.28
		(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
	Motor fuels	-0.09	-1.03	0.02	0.10	0.26	-0.45
		(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)
	Gas	0.18	0.04	-0.69	-0.16	-0.29	0.11
		(0.001)	(0.000)	(0.001)	(0.001)	(0.002)	(0.000)
	Publ Trans	0.01	0.10	-0.06	-0.65	-0.74	0.63
		(0.000)	(0.001)	(0.001)	(0.002)	(0.004)	(0.004)
	Food	0.01	0.06	-0.02	-0.15	-0.10	-0.50
		(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.001)
	Other	0.01	-0.03	0.00	0.05	-0.43	-0.73
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Compensated Price Elasticities

		Price					
		Electricity	Motor fuels	Gas	Publ Trans	Food	Other
Demand	Electricity	-1.43	-0.12	0.16	0.06	0.30	0.82
		(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
	Motor fuels	-0.06	-0.92	0.03	0.12	0.56	0.28
		(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
	Gas	0.20	0.07	-0.66	-0.13	-0.04	0.58
		(0.001)	(0.000)	(0.001)	(0.001)	(0.002)	(0.001)
	Publ Trans	0.03	0.11	-0.05	-0.53	-0.44	1.00
		(0.000)	(0.001)	(0.001)	(0.002)	(0.004)	(0.003)
	Food	0.02	0.08	-0.01	-0.12	0.16	-0.24
		(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.003)
	Other	0.04	0.01	0.02	0.09	-0.12	0.04
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Expenditure Elasticities

		0.96	1.22	0.84	0.85	0.60	1.20
		(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.000)

Standard errors in parentheses

Table 4.2 Probit energy demand (marginal effects)

VARIABLES	(1) electricity	(2) motor fuels	(3) gas	(4) public transp
lnp1	-0.00634***	-0.134***	0.241***	0.160***
	(0.00127)	(0.00596)	(0.00664)	(0.00684)
lnp2	0.0485***	-0.369***	0.0204	0.415***
	(0.00614)	(0.0237)	(0.0269)	(0.0275)
lnp3	-0.0108***	0.150***	0.0558***	-0.106***
	(0.00226)	(0.0117)	(0.0133)	(0.0135)
lnp4	0.00653*	-0.322***	0.242***	0.332***
	(0.00347)	(0.0171)	(0.0193)	(0.0197)
lnp5	-0.0281***	0.794***	0.117**	-1.051***
	(0.0103)	(0.0508)	(0.0570)	(0.0582)
lnp6	-0.00596	-0.335***	-0.998***	0.418***
	(0.0151)	(0.0739)	(0.0825)	(0.0846)
ln(x)	0.00627***	0.317***	0.177***	0.0305***
	(0.000456)	(0.00178)	(0.00216)	(0.00224)
male	-0.00233***	0.156***	-0.000476	-0.0829***
	(0.000647)	(0.00286)	(0.00327)	(0.00336)
age	0.000299***	0.000955***	0.00189***	-0.00212***
	(1.94e-05)	(8.32e-05)	(9.24e-05)	(9.37e-05)
education	0.00103**	0.0758***	-0.0159***	-0.0707***
	(0.000482)	(0.00211)	(0.00246)	(0.00247)
household size	0.000599***	-0.00687***	0.00843***	0.0289***
	(0.000142)	(0.000654)	(0.000754)	(0.000770)
rural	-0.00331***	0.0754***	-0.136***	-0.143***
	(0.000553)	(0.00307)	(0.00336)	(0.00343)
Observations	117,656	117,656	117,656	117,656

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

cant difference with the exception of electricity. Electricity price changes have a slightly regressive effect as opposed to motor fuel price changes, which are clearly progressive. Welfare losses for gas and public transport price increases rise with expenditures until the 20th percentile and start falling from the 50th percentile. As expected from the descriptive analysis in section II, price changes for public transport have the potential to create the largest welfare losses for low and middle income households. Absolute welfare losses are strictly rising with expenditures for all energy goods. Simultaneous price increases for all energy related expenditures lead to an inverse U-shaped distributional impacts curve (figure 4.4). The magnitude of welfare losses is more distributional neutral and smaller in magnitude than welfare losses from food price increases, which are strongly regressive. With multiple price changes, the necessity of calculating second-order welfare effects is visible between the 20th and 90th percentile. First-order effects overestimate the welfare loss up to 10 percent for middle income households.

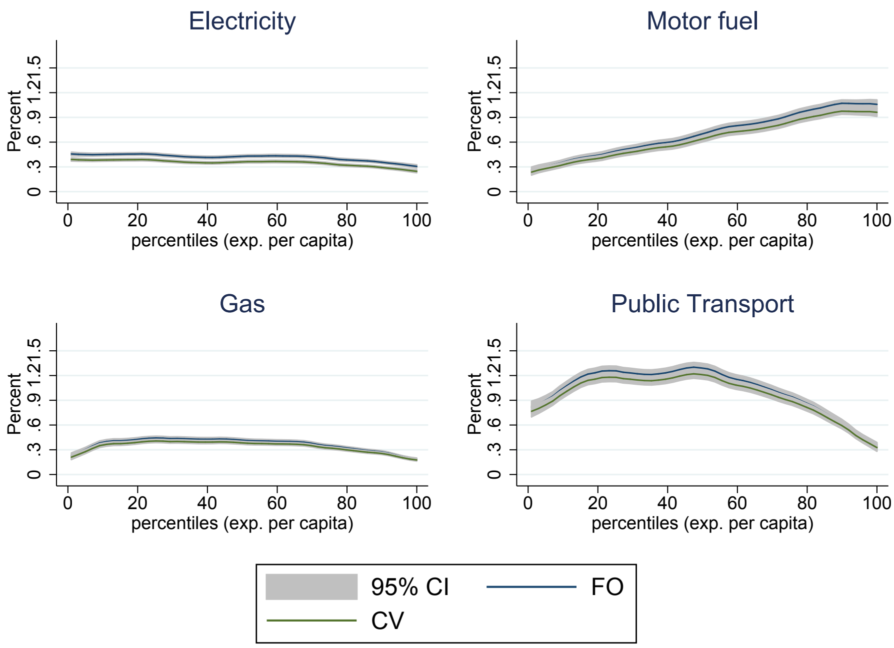

Fig. 4.3 Welfare effects first- and second-order (CV), energy items

As expected from the descriptive analysis of users vs non-users of energy types, distributional results differ significantly for the average user with strictly positive demand for the respective energy good (figure 4.5). While we see almost no difference for electricity, price increases for all other energy items are clearly regressive for the user part of the population. Taking motor fuel as an example, the population average progressive effects can be explained by low car ownership rates of the lower part of the expenditure distribution. For public transport, a major share of rural low income households appears not as dependent on public transport and therefore we find smaller welfare losses than for the rest of the population. Although these differences between users and non-users shed light on heterogeneity in welfare effects within the same income group, the share of the population affected around the poverty lines is more relevant for poverty incidence. Price increases for each energy type separately have quite modest impacts on the wellbeing poverty rate, with differences for each energy good (figure 4.6). We calculate welfare losses for first- and second order effects to assess the importance of taking into account substitution behavior for poverty incidence. Price increases of up to 50 percent for the single energy items produce nearly identical poverty rate

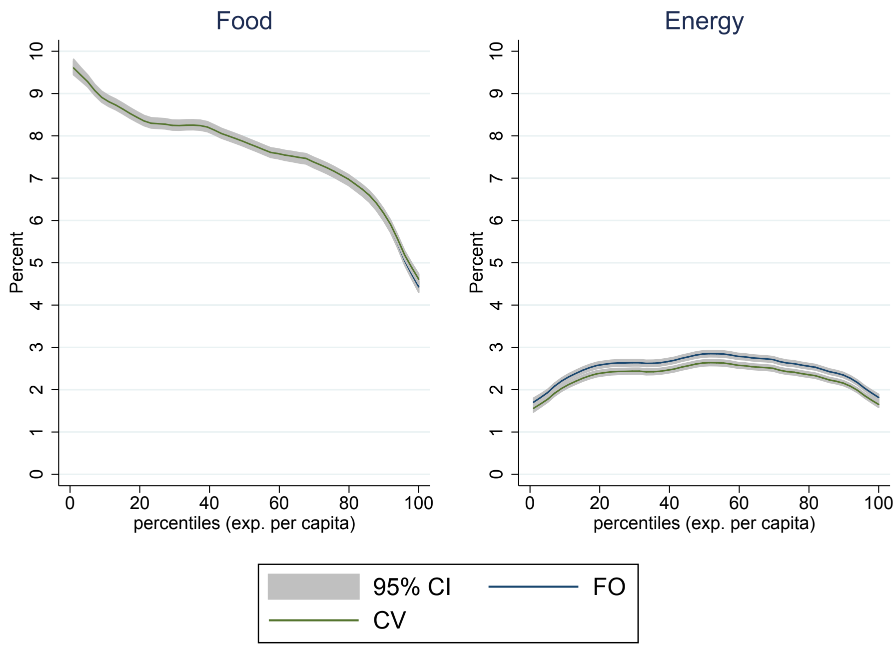

Fig. 4.4 Welfare effects first- and second-order (CV), energy and food

outcomes for first- and second-order effects. Only beyond this range, differences become significant. For joint price increases for all energy goods, the difference between first- and second-order effects starts earlier and is more pronounced. The domestically used energy electricity and gas both show little sensitivity towards price increases with respect to the poverty rate. An electricity price rise of 50 percent would increase the wellbeing poverty rate by 0.5 percentage points maximum. Domestic energy prices for consumers in Mexico are relatively low in international comparison.

Energy price increases in general have less impact on poverty than food price increases, reflected in a steeper gradient in figure 4.6. Nevertheless, at the wellbeing poverty line, a 20 percent price increase on energy has substantial effects on poverty with an increase of 1.4 percentage points in the poverty rate (table 4.4). The on average higher budget shares and associated welfare effects for middle income households also lead to higher increases of the wellbeing poverty rate for all energy goods and for food compared to the minimum wellbeing poverty rate (table 4.3). Additionally to changes in poverty, middle income households close to the poverty line would be disproportionally affected by higher energy prices although technically not defined as poor after the price change.

For each price increase we calculate resulting changes in the household carbon footprint (energy related CO_2 emissions and CO_2 equivalent emissions including CH_4 and N_2O), displayed in table 4.5. Although motor fuel does not have the highest carbon intensity,

Table 4.3 FGT poverty indices (in %), changes from baseline, minimum wellbeing poverty line

	FGT	Electricity	Motor fuels	Gas	Public Transport	Energy	Food
price change	0	0.143	0.099	0.169	0.373	0.785	3.077
	1	0.041	0.043	0.043	0.124	0.259	1.299
	2	0.019	0.022	0.019	0.057	0.122	0.692
+ lum-sum	0	-0.091	-0.481	-0.081	-0.215	-0.775	-1.307
	1	-0.030	-0.159	-0.046	-0.096	-0.323	-0.540
	2	-0.018	-0.084	-0.027	-0.058	-0.180	-0.293
+ PROSPERA	0	-0.213	-0.821	-0.308	-0.601	-1.820	-2.581
	1	-0.115	-0.377	-0.151	-0.330	-0.745	-0.622
	2	-0.067	-0.200	-0.088	-0.183	-0.357	-0.193

Table 4.4 FGT poverty indices (in %), changes from baseline, wellbeing poverty line

	FGT	Electricity	Motor fuels	Gas	Public Transport	Energy	Food
price change	0	0.192	0.316	0.184	0.710	1.440	4.414
	1	0.097	0.127	0.123	0.356	0.720	2.687
	2	0.061	0.074	0.075	0.216	0.438	1.808
+ lum-sum	0	-0.015	-0.311	0.003	-0.043	-0.598	-0.925
	1	-0.043	-0.285	-0.056	-0.088	-0.475	-0.934
	2	-0.035	-0.205	-0.047	-0.086	-0.371	-0.688
+ PROSPERA	0	-0.046	-0.440	-0.117	-0.046	-0.647	-1.647
	1	-0.135	-0.531	-0.170	-0.352	-1.043	-1.571
	2	-0.118	-0.423	-0.151	-0.318	-0.816	-0.972

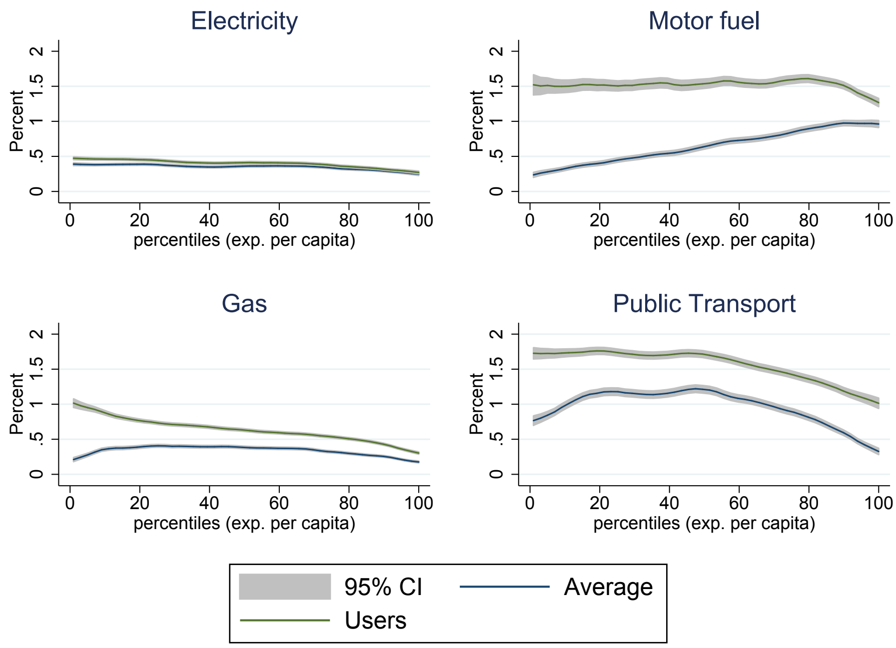

Fig. 4.5 Welfare effects first- and second-order (CV), users vs. average

a motor fuel price increase/tax would create the largest emission reductions, driven by relatively large budget shares. Emission reductions through electricity price changes would also be large, determined by high price elasticities despite relatively small budget shares. Remarkably, taxing gas alone has no observable effect on CO_2 emissions. This seemingly counter intuitive result can be explained by positive cross-price elasticities with electricity. As a clear substitute and with higher carbon intensity, increased electricity demand turns the emission saving from reduced gas use into a small net emission increase. A similar finding can be observed for a tax on public transport, which results in zero emission savings due to substitution with motorized private transport. These findings demonstrate the importance of obtaining a full range of own- and cross-price effects to simulate integrated welfare-environmental models. Multiple price changes for all energy related goods may lead to very strong emission reductions from household demand. Food price increases have, as discussed above, large effects on poverty, and also a significant impact on energy related CO_2 emissions. As households are estimated to have close to zero own-price elasticities for food, the complementary character of gas, public transport and other goods accounts for the energy related emission reduction.

Redistribution of tax revenues leads to moderate progressive welfare effects when lump-sum transfers are used (figure 4.7). Mostly, net taxes are paid by the rich households with the exception of public transport where the middle class pays the bill. When redistributing all

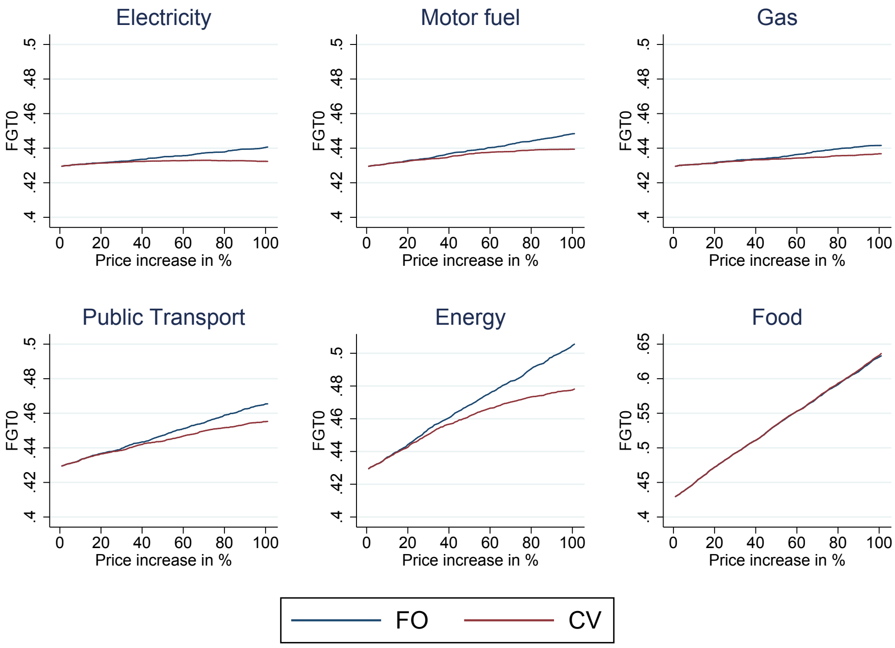

Fig. 4.6 Poverty rate (FGT0, wellbeing poverty line) and price increases

tax revenues solely to PROSPERA recipients, progressivity becomes very strong with large welfare gains around 11 percent of expenditures for the poorest households in the case of motor fuel or public transport taxes. Compared to the pure lump-sum scheme, households are less well compensated starting at the 50th percentile which is also above the moderate poverty line. As a result, the poverty rate decreases by 0.65 percentage points at the wellbeing poverty line in the case of a simultaneous tax of 20 percent on all four energy goods and redistribution via PROSPERA. On the other hand, poverty measured at the minimum wellbeing poverty line reacts more sensitively to redistribution trough the relatively large compensation amounts. In this case and redistribution via PROSPERA, we find a reduction in the poverty rate of 1.8 percent. CO_2 reductions are slightly larger when redistribution takes place via PROSPERA than via universal lump-sum transfers, but differences are small. When taxing all energy related goods with a 20 percent tax rate and tax revenue is fully redistributed via PROSPERA, household CO_2 emissions are calculated to be 9.5 percent smaller than in the baseline and 1.5 percent less than without redistribution. On the other hand, a tax on food with a simultaneous redistribution of tax revenues has positive effects on household CO_2 emissions. Driven by increased demand for direct energy and other goods, the positive income effect from the relatively large redistribution amount has a strong effect on direct energy demand despite the negative cross-price effects with energy goods such as electricity.

Table 4.5 CO_2(e) emission impacts energy price changes (20%)

		Electricity	Motor fuel	Gas	Public Transport	Energy	Food
price change	CO_2	-4.7%	-5.9%	0.0%	0.0%	-10.8%	-2.1%
	CO_2e	-2.8%	-3.1%	-0.1%	-1.2%	-7.3%	-3.1%
+ lum-sum	CO_2	-4.5%	-5.3%	0.3%	0.7%	-9.1%	3.5%
	CO_2e	-2.6%	-2.5%	0.2%	-0.5%	-5.5%	2.4%
+ PROSPERA	CO_2	-4.5%	-5.4%	0.3%	0.6%	-9.3%	2.5%
	CO_2e	-2.6%	-2.5%	0.2%	-0.5%	-5.6%	2.0%

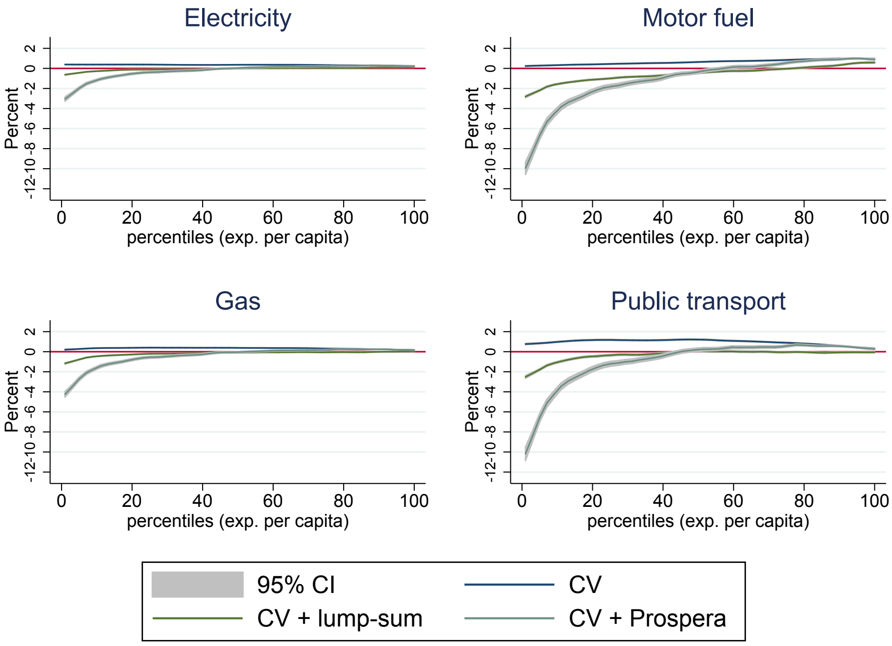

Fig. 4.7 Welfare effects redistribution scenarios

4.4.2 Carbon tax

The first-order welfare and poverty effects of a carbon tax in Mexico have been analyzed in chapter 3. We take calculated sector specific price changes from chapter 3 and apply it to our product categorization to check upon the validity to use first-order effects and calculate the short run CO_2 emissions reduction potential when price increases are fully shifted to consumers.[9] Approximate price increases for a 25 USD/tCO_2 tax and for two different tax

[9] See table C.1 for the aggregation scheme.

bases are displayed in table 4.6. Considering that the tax rate in 2014 was at 3.5 USD/tCO_2, we focus on 25 USD/tCO_2 scenario as an upper bound of potential tax increases in the short term. Price changes for households are most severe for electricity, followed by motor fuel and gas. Public transport and food items are less affected by taxing energy related CO_2 emissions. Food prices are clearly more sensitive to taxing N_2O and CH_4 while direct energy items are hardly affected. Generally, carbon tax induced price changes are smaller than discussed in the previous section on energy and food price changes, although the simulated tax rate can be considered non-marginal.

Table 4.6 CO_2 intensities and price changes carbon tax

		CI (kg/MXN)		Price Change (t = 25 USD)	
	item	CO_2	CO_2e	CO_2	CO_2e
1	Electricity	0.290	0.297	9.0%	9.2%
2	Motor Fuel	0.217	0.222	6.7%	6.9%
3	Gas	0.140	0.140	4.3%	4.3%
4	Public Transport	0.029	0.031	0.9%	1.0%
5	Food	0.020	0.070	0.6%	2.2%
6	Other	0.013	0.022	0.4%	0.7%

The first- and second order effects are plotted in figure 4.8 and we observe that their 95 percent confidence intervals in the calculation of average welfare effects per percentile clearly overlap. This result holds despite the fact that electricity prices are a major channel of carbon tax induced welfare losses and the finding of a large estimated own-price elasticity. The magnitude of electricity price changes in the range of 9 percent does not necessarily require the estimation of demand elasticities. In Scenario I, taxing only energy related CO_2 emissions, welfare effects are slightly progressive in the range of 0.9 and 1.1 percent for lower and higher income households respectively.

When incorporating CH_4 and N_2O in the tax scheme, welfare effects are overall regressive and particularly severe for low income households at 2 percent of total expenditures. The much higher welfare effects are mostly caused by food price increases. Considering the inability of households to substitute away from food expenditures, this scenario has larger welfare and poverty effects. These are generally rising with the tax base with a 1.1 percentage points increase in the wellbeing poverty rate (table 4.7). As in the case of energy price increases, the moderate wellbeing poverty rate is more affected than the minimum wellbeing poverty rate. Redistribution via lump-sum transfers or PROSPERA can turn the welfare effects clearly progressive, poverty indicators even improve over all dimensions.

The short-run emission reduction potential through consumer substitution is at 5.6/3.5 (CO_2/CO_2e) percent of total household induced CO_2/CO_2e emissions and rises up to 6/4 (CO_2/CO_2e) percent in Scenario II. The taxation of CH_4 and N_2O does not only lead to adverse poverty effects, the additional short-run CO_2e emission saving potential is also very limited.

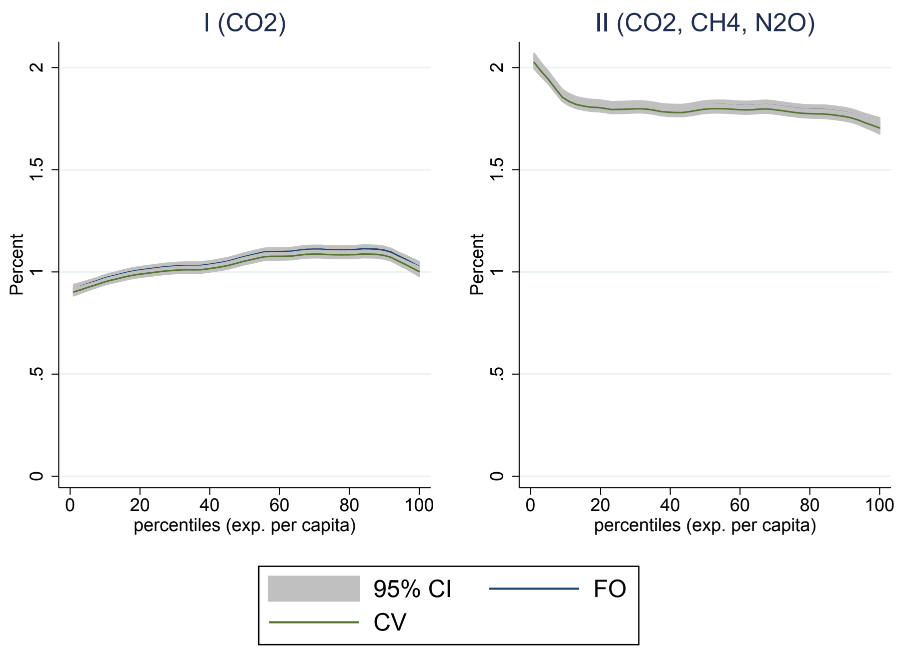

Fig. 4.8 Welfare effects of carbon taxes

It is important to consider however, that these simulated emission reductions are relative to a baseline with zero income growth and tax revenues are completely reinvested carbon free. Additional to expected income growth, redistribution of tax revenues to households in the form of cash transfers, tax rebates or the increased use of public goods inevitably leads to the use of goods produced with fossil fuels if the energy system remains untransformed. In the case of direct cash transfers to households, the CO_2 emission saving potential can shrink to 83 percent of the reductions achieved in scenarios without redistribution. Taking into account CH_4 and N_2O, the wider tax base generates large tax revenues and lump-sum transfers which in turn lead to large income effects and smaller CO_2 and CO_2e savings which are reduced to 75 and 62 percent respectively. Redistribution via PROSPERA leads to slightly larger CO_2 emission reductions as already observed in the case of energy price changes. Considering the problematic link of taxing CH_4 and N_2O with food prices, taxing CO_2 alone provides an option for an ambitious short-run climate policy with moderate welfare effects that could be turned into welfare gains with proper redistribution schemes.

Table 4.7 FGT changes carbon tax

	FGT	Minimum wellbeing		wellbeing	
		Tax Scenario			
		I (CO_2)	II(CO_2, CH_4, N_2O)	I (CO_2)	II(CO_2, CH_4, N_2O)
Carbon Tax	0	0.399	0.755	0.723	1.186
	1	0.140	0.264	0.392	0.651
	2	0.066	0.130	0.233	0.406
+ Lump-sum	0	-0.407	-0.607	-0.061	-0.301
	1	-0.147	-0.228	-0.189	-0.347
	2	-0.083	-0.126	-0.161	-0.272
+ PROSPERA	0	-0.407	-1.505	-0.292	-0.493
	1	-0.147	-0.633	-0.518	-0.854
	2	-0.083	-0.311	-0.446	-0.686

Table 4.8 CO_2(e) emission impacts (USD 25/t CO_2(e))

		Tax Scenario	
		I (CO_2)	II (CO_2, CH_4, N_2O)
Carbon Tax	CO_2	-5.6%	-6.0%
	CO_2e	-3.5%	-4.0%
+ Lump-sum	CO_2	-4.7%	-4.5%
	CO_2e	-2.6%	-2.5%
+ PROSPERA	CO_2	-4.9%	-4.7%
	CO_2e	-2.6%	-2.4%

4.5 Discussion and conclusion

We simulate the short-run poverty and distributional effects of energy price changes and carbon taxes in a partial equilibrium framework. We estimate a full matrix of substitution elasticities, test first- versus second-order welfare effects and find the latter are only slightly different than the former as in the case of electricity but differ with multiple price changes. Despite this finding, two practical reasons speak against the abandonment of demand estimation in our context. First of all, checking on the validity of using first-order effects is preferable over assuming it. Secondly, without estimated substitution elasticities we are unable to calculate the CO_2 emission saving potential that comes from household consumption. The latter is usually lacking in prior literature.

By simulating stylized price increase scenarios, we find only motor fuels to unfold progressive effects. Taxing electricity, gas and public transport is regressive, although in the latter case the middle class is most affected. Important to consider is also the heterogeneity within income percentiles. For actual users with positive demand for energy items, price increases are regressive. To put energy price changes into perspective, we find that food price increases have significantly larger welfare effects. Households spend a larger fraction on food products than on energy and show small sensitivity to prices reflected in a close to zero own-price elasticity. Middle income households close to the wellbeing poverty line would be more affected by higher energy prices than low income households. Although the smaller effects on extreme poverty are welcome from a development perspective, the political economy behind this pattern could be problematic. The progressive distribution pattern of welfare effects resulting from a carbon tax is largely driven by private motorized transport. Though the absolute monetary losses are small for households, the public opinion on environmental policy reforms appears to be quite sensible to gasoline price changes.

We also simulate a carbon tax at USD 25 per t CO_2 and find slightly progressive welfare effects and substantial emissions reductions. The additional taxation of CH_4 and N_2O has the potential to create large price changes in the agricultural sector which makes their incorporation into a carbon tax regime an unsuitable candidate for creating poverty and environmental synergies in short-run climate policies. Considering the problematic link of taxing CH_4 and N_2O with food prices, taxing CO_2 alone provides an option for an ambitious short-run climate policy with moderate welfare effects that could be turned into welfare gains with proper redistribution schemes. The calculated emission reductions through energy and carbon taxes must be understood as household consumption induced emission reductions relative to a baseline with no income growth. Emission reductions through substitution by households can be quite substantial even in the case of small price changes. Income and related consumption growth on the other hand reduce the emission saving potential. Taking into account the latter through redistribution via cash transfers, the initially large numbers become significantly smaller but remain substantial. Unsurprisingly, redistribution of simulated tax revenue can turn any regressive outcome progressive and reduce poverty. A targeted transfer through a social welfare program (PROSPERA) proofs to be preferable in terms of poverty and emission outcomes. Since compensation amounts are relatively large for lower income households, poverty reduction through redistribution is clearly more visible at the lower, minimum poverty line and also creates less additional consumption effects and associated emission increases.

Chapter 5

The effects of energy price changes: Heterogeneous welfare impacts, energy poverty and CO_2 emissions in Indonesia

5.1 Introduction

Fuel and energy prices are typically subject to heavy government intervention in many countries. Energy is subsidized to make it affordable and to shield domestic prices from international price fluctuations. In addition, transport fuels are heavily taxed in a number of countries because of negative externalities they create. These subsidies and taxes can constitute a heavy burden on government budgets or alternatively a reliable source of tax revenue. In recent years, climate change mitigation policies have been adding to the reasons to regulate energy prices. With regard to energy pricing, one particular policy option, abolishing fuel subsidies in developing countries, is often seen as a win-win policy, as it reduces distortions, internalizes negative climate externalities, and, on top of that, is progressive as it hurts richer, fuel-consuming households more than poorer households (Arze del Granado et al., 2012; Clements et al., 2013; Sterner, 2011). This paper adds to the literature that examines the latter assertion. The direct welfare effects of energy price changes for households depend on the magnitude of the price change, the relative importance of energy items in the basket of commodities and finally on the ability and willingness to substitute the more expensive good to deal with price shocks. In addition, indirect (general equilibrium) effects are triggered by changing production costs and hence the prices of other goods (and intermediate inputs). These changes will eventually affect labor demand and wages. Such effects are taken into account by general equilibrium modelling exercises. In this paper, we analyze the welfare impacts of energy price changes using a partial equilibrium approach based on a detailed empirical model of household energy demand in Indonesia. Since the majority of energy subsidies are in the form of fixed prices for consumers, indirect effects through wages and employment are unlikely to be of major importance. Additionally, the use of a CGE would come with a high demand for empirically unavailable parameter values and a higher energy item aggregation than needed in our case. Previous partial equilibrium studies on the impact of fuel subsidies in low and middle income countries have typically come to the conclusion that fuel subsidy (tax) cuts (increases) tend to be progressive.

We improve on and add to existing work in three ways: First, we model behavioral responses to price changes, i.e. we capture second order effects that are typically not accounted for in previous work. Second, we explore in detail the heterogeneity of impacts caused by the ownership of energy-processing durables, such as private transport vehicles, electric appliances or cooking stoves. These durables are acquired by households according to the amount of services the household needs and some of them are not easily substituted, particularly transport vessels. While it is true that low income households have lower ownership rates of many energy processing durables, a considerable share among the poor has high service needs due to occupational or geographical circumstances. It is these households that may be strongly affected by certain fuel price changes. Third, we also examine the quality and quantity effects of price changes on energy services, which may have a significant impact on individual wellbeing. Thereby, we extend the welfare analysis beyond the money metric utility effects and look at energy poverty understood as a condition of missing or imperfect access to reliable and clean modern energy services. Without affordable alternative technological solutions to the use of fossil fuels, rising energy prices may seriously affect the amount of energy services that households continue to use for basic living requirements.

In Indonesia, consumer energy prices have been regulated by the government for a long time with a recent change in subsidy policies, facilitated by dramatically falling oil prices. This makes the country an ideal place to study the welfare implications of energy price changes. In addition, our work is likely to remain highly relevant to the country's policy-makers: When oil prices rise again in the future and current government policies continue to phase out subsidies with flexible pricing mechanisms close to market levels, the price of energy will rise for households. We analyze this scenario of rising energy prices for a set of commercial energy items used by households and estimate the impact on household welfare, energy poverty and demand related carbon emissions.

The rest of the paper proceeds as follows. We first describe the current situation of consumer energy prices and the energy subsidy scheme for consumers in Indonesia (section 5.2). We then provide an overview of the literature related to energy price changes with a focus on low and middle income countries (section 5.3). Section 5.4 presents the price and survey data as well as some descriptive statistics. In section 5.5 we describe the theoretical and empirical models underpinning our welfare analysis. The results are presented in section 5.6 and we conclude in section 5.7 with some policy recommendations.

5.2 Consumer energy prices and subsidies in Indonesia

Energy prices for households in Indonesia have traditionally been set by the government below international market price levels. These subsidies are argued to make access to energy affordable to the poor. In fossil fuel rich countries, like Indonesia, this policy is also motivated by the idea of sharing natural resource wealth with its citizens. Subsidies have been the dominating domestic energy policy instrument for decades but the high costs have put considerable pressure on public finances in recent years, and much more so since 2009 when the country became a net oil importer and left the OPEC. Today, the country is more oil-dependent than ever before, as from 2000 to 2013, total final energy consumption and the per capita final energy consumption increased by over 80 percent and 55 percent respectively (MEMR, 2014).[1] Very likely, this increased oil-dependence can be partly ascribed to fuel subsidies. As a reaction to the fiscal pressure, the government implemented significant subsidy reductions in 2005, 2008 and 2013, i.e. during a time when rising oil prices pushed up fuel subsidy expenditures that could no longer be sustained. Figure 5.1 shows nominal energy prices for electricity, gasoline, kerosene, and LPG, respectively, from 2008 onwards.[2] All three subsidy reforms were accompanied by compensation programs, which helped to gain public acceptance. At the end of 2012, Indonesia had the lowest fuel prices of any net-oil consuming nation worldwide and fuel subsidy expenditures increased up to 21.2 percent of total central government spending (World Bank, 2013). In June 2013, the government decided to increase prices on gasoline and diesel up by 44 and 22 percent, respectively. Public protests did not spread too far and subsidy cuts were accompanied with two compensation packages, including short-term unconditional cash transfers, increased food distribution and additional spending in infrastructure programs. In late 2014, the newly elected government announced a complete phase-out of fuel subsidies in the coming years. As a result of this policy and low world oil prices, the price for automotive fuels decreased with subsequent rises in March 2015. The government's concern about the social implications of fuel subsidy reform led it to treat several fuel items differently. Subsidies on kerosene, today a less used fuel for lighting and cooking source for the rural poor, have not been trimmed down as much

[1] Population growth in the same period has been around 17 percent.

[2] Data on general energy prices are from the Ministry of Energy and Mineral Resources.

as those on gasoline and diesel.[3] Recent subsidy reform has also made a distinction on the purchasing side, when subsidies on both kerosene and gasoline have been completely abolished for industrial consumers. When international oil prices are low, gasoline subsidies may be completely phased out for the time being. However, when oil prices start to rise again and subsidies are abolished as politically communicated, households will face non-marginal price increases that, depending on the scenario for international markets could raise prices by 100 percent and more. We focus explicitly on the main energy items that households use, including electricity and fuels such as gasoline, kerosene and LPG. Traditional fuels, i.e. firewood and biomass, are widely used as well, particularly in rural areas. However, we have no information on prices for these fuels, neither in the survey data nor from external sources. For electricity demand, price discrimination between different users is established through a progressive block tariff schedule that results in higher prices per kwh with higher installed power capacity and demand. Households pay the lowest price on average compared to industry and business (figure 5.1) and also face the smallest price increases over the last years. With an estimated production price of 1200 IDR per kwh (about 0.07 Euro at 2015 exchange rates), only few customers pay an unsubsidized price and tariffs for households as low as 150 IDR reveal the dimension of subsidies paid in this sector. For transport fuels, different products with varying octane qualities exist but low quality gasoil, mainly used for motorcycles, dominates the market. While the higher quality gasoline fuels (92 and 95 octane) have been closer to international market prices, the price of lower quality gasoline and diesel has been fixed by the government at comparatively low levels with recent price fluctuations towards international price levels. There are differences between the official retail price and measured prices at the consumer level, particularly in rural areas where transport costs and additional trading margins in informal market add to the official price. Kerosene, a multi-purpose fuel for cooking and lighting, has not seen a change in retail prices since 2008 but rural consumer nevertheless pay an increasingly higher price over the last years. The increasingly used fuel for cooking, LPG, comes in different bottle sizes and the prices are regulated accordingly. The smallest size is 3kg with the lowest price and no change over the last years. Prices for 12kg bottles increased recently while the 50kg bottles move with market prices. Like transport fuels, LPG is more expensive in rural than in urban areas on average.

[3]In 2007 the government launched a kerosene–to–LPG transition program that included the disbursement of more than 48 million free LPG start–up packages and subsidized the price for small LPG tanks (3kg).

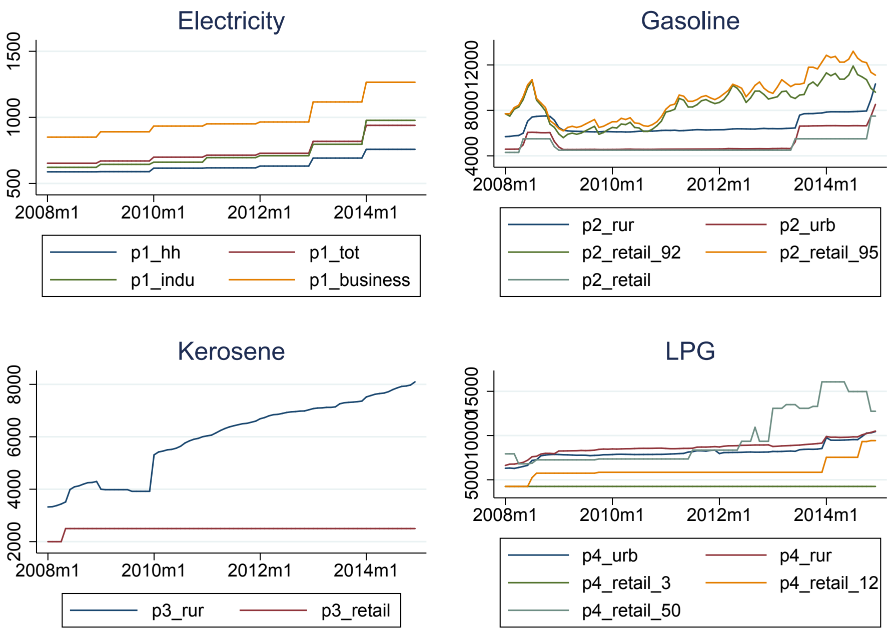

Fig. 5.1 Nominal energy prices over time

5.3 Literature review

Shah and Whalley (1991) and Shah and Larsen (1992) were among the first to warn of applying conventional wisdom in assessing the incidence of environmental taxes for developing countries. They hinted at the fact that, with lower shares of energy expenditures in the consumption basket of the poor, distributional effects of energy related taxes in developing countries can generally be expected to be progressive. Earlier work on Indonesia by Pitt (1985) finds that kerosene subsidies benefited the urban and wealthy households the most. In addition, they cannot support the notion that kerosene subsidies would help to address deforestation externalities. Olivia and Gibson (2008) estimate a five good household energy demand system for Indonesia with a correction procedure for quality effects suggested by Deaton (1988). Based on a marginal tax reform approach by Ahmad and Stern (1984), increasing taxes on energy is found to be desirable from both an efficiency and equity perspective. Other work on energy prices and subsidies for Indonesia predominantly use Computable General Equilibrium (CGE) models. Clements et al. (2013), for example, simulate the effects of a price increase for petroleum products and find a decline in aggregate household consumption with high income urban households suffering the highest losses. Another CGE analysis with a highly disaggregated household sector by Yusuf and Resosudarmo (2008) – in a similar scenario with rising fuel prices –, also find progressive effects for transport fuels, but regressive effects of higher Kerosene prices. Dartanto (2013) uses a CGE model with a disaggregated household sector to explicitly look at the effects of fuel subsidy reductions on the poverty rate. He finds a slight increase in the poverty headcount with no recycling of revenues. Yet, a complete removal of fuel subsidies and a partial reallocation to other government spending items and transfers has the potential to slightly reduce poverty. Durand-Lasserve et al. (2015) also use a CGE to assess the distributional impacts of energy subsidy reforms and find subsidy removals to be generally regressive. They simulate different redistribution schemes and find lump-sum transfers to change the distributional impacts towards progressivity. For other low and middle income countries, there is some evidence for a progressive (regressive) impact of fuel taxes (subsidies). Sterner (2011) presents a collection of mostly first-order, partial equilibrium studies on the impact of transport fuel taxes on the poor in Mexico, Costa Rica, China, India, Ethopia, Ghana, Kenya, Tanzania and the impact of reducing transport fuel subsidies in Iran. The general result is that poor households face a lower tax burden relative to their income as richer households, leading to a progressive income distribution effect in all cases. The main reason is that poorer households tend to spend relatively little on transport fuels. Recently there is also an increasing interest in energy subsidy reforms as reflected by a growing literature for low and middle income countries. Arze del Granado et al. (2012) provide a review of fuel subsidies for 20 countries and find that the top income quintile receives as much as six times more in subsidy payments than the bottom quintile. In general, there appears to be no disagreement that – in developing countries – transport fuel subsidies benefit the rich more than the poor. Yet, there is no work on energy subsidies in general, i.e. subsidies on electricity and cooking fuels are typically ignored. While the heterogeneity of impacts of price changes across the income distribution has been scrutinized in most empirical work, other possible sources of impact heterogeneity have received less attention. The presence of certain energy-related household needs, for example the need for transport in remote areas, may have important implications for welfare impacts of price changes. Specifically, some households, and more so poorer ones, do spend a higher than average share of their budgets on energy and this may introduce substantial impact heterogeneity. Additionally, the issue of energy poverty is virtually absent from the discussion on fuel taxes and subsidies.

5.4 Household energy use and energy poverty

We use household expenditure data from the Indonesian Survei Sosial Ekonomi Nasional (SUSENAS), a cross-section survey collected annually by Badan Pusat Statistik (BPS) Indonesia.[4] Drawing on the survey data, the poverty rate in Indonesia was at 12 percent in 2013 using the national poverty lines provided by BPS Indonesia with the majority of the poor living in rural areas (see also table 5.1).[5] The SUSENAS survey has a detailed expenditure module with reported expenditures and quantities on electricity (in kwh), gasoline (in l), kerosene (in l) and liquefied petroleum gas LPG (in kg). In addition, other expenditures for transport are reported, including spending on public transport, airfares, and marine transport. Based on these data, Figure 5.2 shows the patterns for all energy (electricity, gasoline, kerosene, LPG, other transport and firewood), modern energy (electricity, gasoline, kerosene and LPG; used in the later analysis), transport energy (gasoline and other transport) and domestic energy (electricity, kerosene, LPG and firewood) expenditures over the income distribution, divided into percentiles of total household per capita expenditure.[6] Due to the discrete decision to obtain major energy-consuming durables, we distinguish between the average user in the sample including zero demand (demand >= 0) and the average user with strictly positive demand (demand > 0). This is a simple approximation to the abovementioned heterogeneity in energy spending patterns between households that, in contrast, may be similar in terms of household per capita income. In the case of aggregated energy expenditures, this hardly makes a difference but it is very relevant in the analysis of single energy items. In general, energy expenditures rise over the expenditure distribution which appears to be driven by transport expenditures. Modern domestic energy use is only absent for some households below the 20th percentile, and the share of households relying solely on traditional energy sources for cooking and lighting is below 10 percent among this group. A more detailed look into the expenditure patterns of single energy items for rural (figure 5.3) and urban (figure 5.4) households provides some interesting insights here. For gasoline demand, the following pattern emerges: the budget shares for gasoline of the richest households is about twice as high as the average poor household's budget share. Yet, those households in the lower part of the income distribution who actually use gasoline have a similar budget share as the rich. This shows that the sole look at averages even within income groups is not sufficient, in particular if policy makers are interested in identifying potential losers. 30 percent of the poorest households use gasoline, most of them as an input to motorcycle transport. This differentiation is not necessary for electricity demand, as, according to the

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

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

[6]Nonparametric distributional curves are calculated with kernel-weighted local polynomial smoothing using an epanechnikov kernel function with degree 0 and bandwith 1.15.

survey data, about 90 percent of the population have non-zero electricity demand. This reflects relatively high grid access in Indonesia, reported to be around 76 percent in 2012 (IEA, 2014). The difference can be explained by electricity coming from local power supply and diesel generators. Electricity budget shares are generally rising with income and differ between rural and urban areas. The average urban household spends 1 percentage point more of his income on electricity than the average rural household. While Kerosene is a multi-purpose fuel, LPG and firewood are mostly used for cooking. Over time, kerosene has become the least popular fuel in Indonesia with only 30 percent of households exhibiting positive demand. It is still more used in rural areas and, somewhat surprisingly, not just by low income households but with slightly higher budget shares by middle and higher income households. LPG and firewood might be close substitutes in general, but, as expected, low income rural households still depend heavily on firewood and LPG is becoming the dominant cooking fuel for urban households – now used by 51 percent of the population.

In contrast to regular consumption goods, energy use is typically a two-step decision process with the first step being a discrete decision to own a durable which converts energy into some usable form to enjoy the desired energy service. A case in point is of course private transport. Not surprisingly, demand for gasoline can be well explained by the ownership of private transport vehicles, dominated by motorbikes in Indonesia. Once households own a motorbike, they tend to spend a similar share of their income on gasoline – irrespective of their income levels. This is illustrated in Table 5.1 that combines poverty status, ownership of private transport means, and gasoline expenditure shares. The national ownership rate of private transport means stands at 65 percent in our dataset. The rate in urban areas is 74 percent and significantly lower but still considerable with 58.2 percent in rural areas. Among the poor, still 37.1 percent own a vehicle, typically a motorbike. For these income poor motorbike owners, the average budget share for gasoline is 5.2 percent, only 0.1 percentage points less than the share of the non-poor. Note also that urban poor vehicle owners spend an even higher budget share on gasoline than the urban non-poor. Maybe somewhat contrary to expectations, we do not find major differences in transport-related energy demand between rural and urban households. Note that the residual category includes diverse transport modes such as local public transport as well as air travel. The latter is likely to be the main reason why budget shares increase with higher incomes and rich rural households with positive demand have higher budget shares than their urban counterparts. For lower income households, the share of public transport might be higher in this category, but we are unable to further distinguish between transport modes. Other minor transport energy items are motor oils and diesel, with the latter likely to be relevant to prices of public transport. The direct use of diesel by households is negligible in Indonesia. Opposed to transport, expenditures for firewood (also includes other undefined fuels) decline with rising incomes and the usage rate declines steeply (figure 5.5). Rural households clearly use more firewood than urban households, reflected in higher usage rates and budget shares.

Our analysis of energy demand patterns reveals interesting insights into an often overlooked dimension in the distributional analysis of energy price changes: energy poverty. The International Energy Association defines energy poverty as "the lack of access to modern energy services. These services are defined as household access to electricity and clean cooking facilities [e.g. fuels and stoves that do not cause air pollution in houses]" (IEA, 2014).[7] We therefore focus on the domestically used energy items electricity, kerosene and LPG, for which expenditure information is available in the household survey. The used quantities are transformed to physical, normalized units (kilograms oil equivalent, kgoe) and summed up to household energy use per capita. Two different energy poverty approaches are subsequently defined and will help us to understand the sensitivity of the chosen poverty lines. First, we define poverty cut-offs at 50 kgoe (kilogram of oil equivalent) of final energy per capita and year in the form of modern fuels used for cooking and a minimum amount of electricity resulting in the energy poverty Line (EPL) 1, similar as in Modi, Vijay et al. (2005). Since quantity information for firewood is missing, we calculate household energy use per capita exclusively based on modern fuels. Therefore, energy poverty is strictly defined as a lack of use of modern energy and not as total energy use which would include biomass.

Table 5.1 Gasoline demand, vehicle ownership and poverty

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

[a] Average budget share over population including zero demand
[b] Average budget share over population excluding zero demand
[c] Ownership rate for private transport vehicle(s)
[d] Ownership rate for motorcycle(s

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

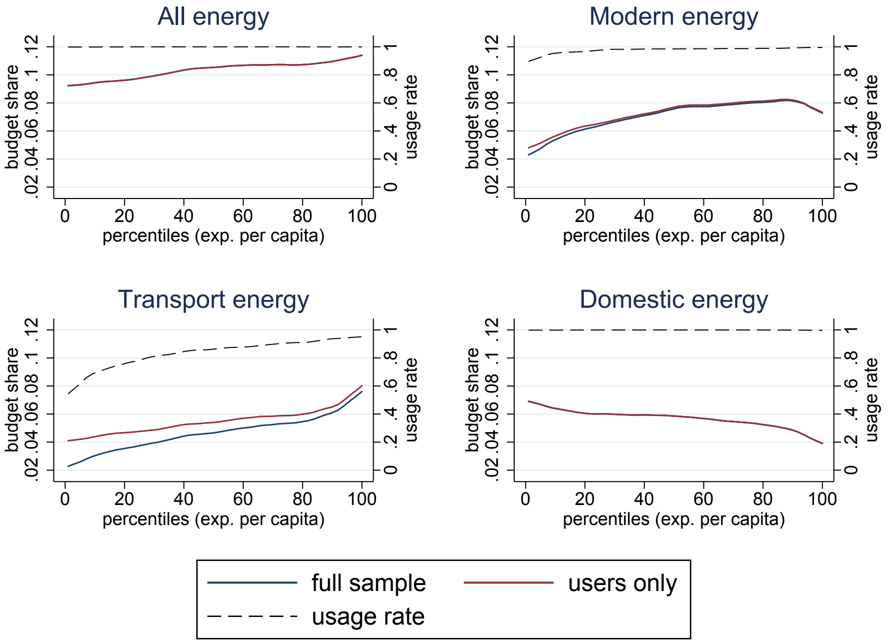

Fig. 5.2 Energy expenditure shares

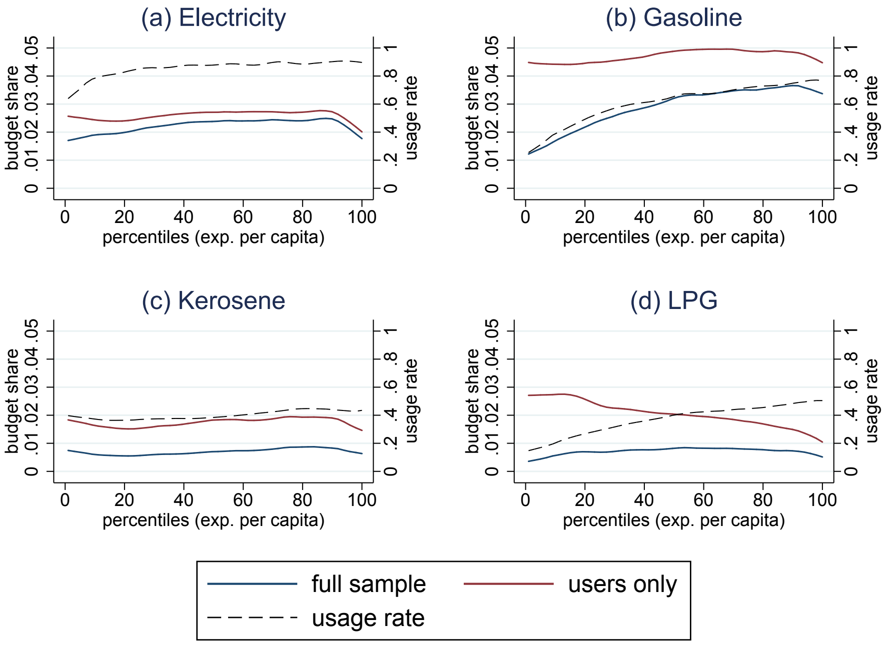

Fig. 5.3 Rural energy expenditure shares and usage rates

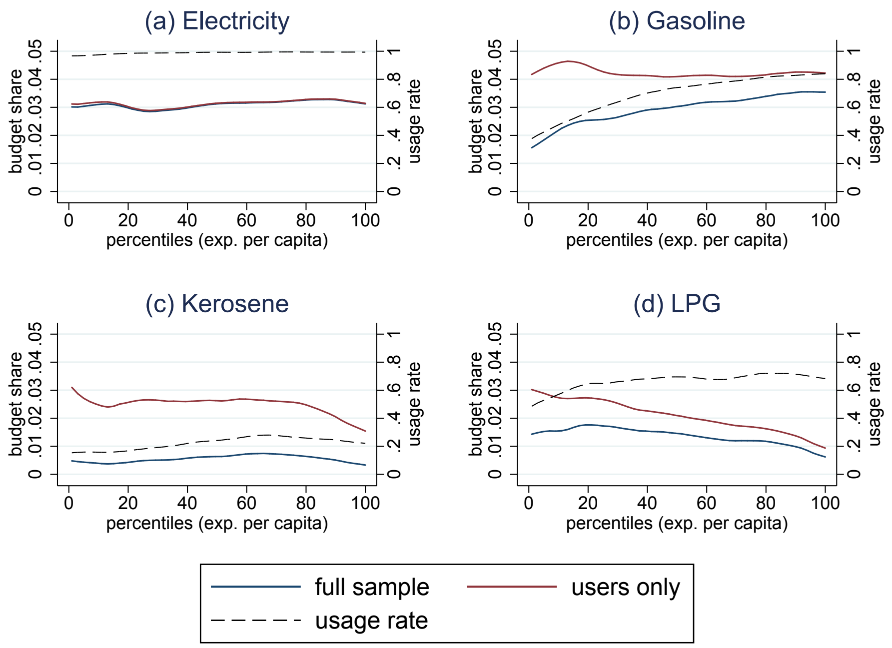

Fig. 5.4 Urban energy expenditure shares and usage rates

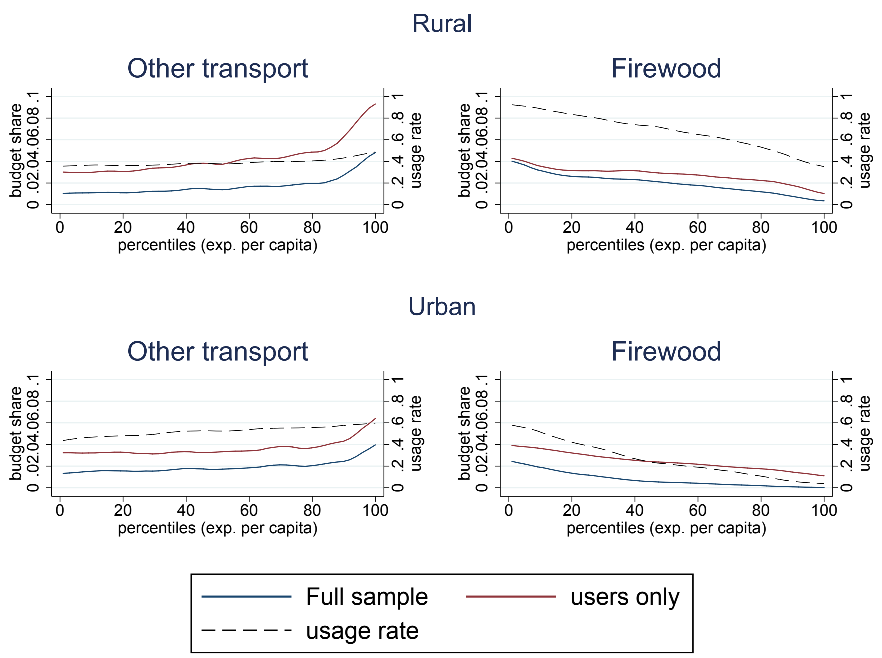

Fig. 5.5 Urban and rural energy expenditure shares and usage rates

Secondly, we define an alternative energy poverty line (EPL 2) at the expenditure poverty line inspired by Foster et al. (2000). We do this by transforming demanded quantities of all "modern" energy items into kgoe and perform a nonparametric kernel-weighted local polynomial regression of the quantity used per energy item on total household expenditures per capita for the reference year 2013.[8] The calculated value at the per capita expenditure poverty line can then be directly interpreted as our energy poverty line at which we calculate FGT energy poverty indices. We refrain from calculating a "transport poverty line" because of conceptual and empirical issues, such as the difficult comparability between urban and rural energy needs and the missing public transport data. Table 5.2 displays the calculated FGT energy indices and the per capita energy poverty line EPL 2 which is considerably smaller than EPL 1 at around 22 kgoe. Although this poverty line is at a relatively low level, the national energy poverty rate is close to 30 percent, dominated by the rural energy poverty rate of 43 percent. To be clear, there are many households not defined as income poor but do not use more modern energy than the average household at the poverty line. Based on EPL 1, the national energy poverty rate is above 60 percent. Since many, particularly rural households use firewood for cooking and we excluded it from the analysis, the magnitude is not particularly surprising.

Table 5.2 Energy poverty

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

EPL 2 poverty line: 21.82 kgoe

5.5 Welfare measurement, demand estimation and CO_2 Emissions

5.5.1 Demand system

There is an extensive literature on the estimation of demand functions based on economic theory. Since the seminal work of Stone (1954), a significant amount of research has been produced, with Deaton and Muellbauer's (1980b) Almost Ideal Demand System (AIDS)

[8]See Fan and Gijbels (1996) for further information on kernel-weighted local polynomial regression.

(Deaton and Muellbauer, 1980a) and the quadratic extension of the AIDS, the QUAIDS by Banks et al. (1997) among the more prominent ones. The estimation of QUAIDS has been applied to the energy context by West and Williams III (2004), Labandeira et al. (2006), Nikodinoska and Schröder (2016) and Tiezzi and Verde (2016). According to our knowledge, no demand system specification of this form has been applied to the energy context in low and middle income countries before. For India, Gundimeda and Köhlin (2008) estimate an LA-AIDS differentiated by income for rural and urban households separately. They report a full range of substitution elasticities for a four good energy demand system but no welfare effects. More recent developments in the field are towards even higher nonlinearity in parametric systems (Lewbel and Pendakur, 2009). For our analysis we use the well-established QUAIDS framework since observed Engel curves appear to be well approximated by a quadratic relationship between budget shares and logarithmic transformed expenditures. Rank three quadratic logarithmic budget share systems have an indirect utility function of the following form:

$$\ln V = \left\{ \left[\frac{\ln x - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1} \tag{5.1}$$

The price indexes $\log[a(p)]$ and $b(p)$ are defined as:

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \tag{5.2}$$

$$b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \tag{5.3}$$

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

$$\lambda(p) = \sum_{i=1}^{n} \lambda_i \ln p_i \tag{5.4}$$

With $\sum_i \lambda_i = 0$. The derived expenditure share system is:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \left[\frac{x}{a(p)} \right] + \frac{\lambda_i}{b(p)} \left\{ \ln \left[\frac{x}{a(p)} \right] \right\}^2 \tag{5.5}$$

Where w_i is the share of commodity (group) i of total non-durable expenditures x. To be consistent with utility maximization, the following restrictions need to hold:

Adding-up

$$\sum_{i=1}^{n}\alpha_i = 1; \quad \sum_{i=1}^{n}\gamma_{ij} = 0; \quad \sum_{i=1}^{n}\beta_i = 0; \quad \sum_{i=1}^{n}\lambda_i = 0 \tag{5.6}$$

Homogeneity

$$\sum_{j=1}^{n}\gamma_{ij} = 0 \tag{5.7}$$

Symmetry

$$\gamma_{ij} = \gamma_{ji} \tag{5.8}$$

Income /Expenditure elasticities can be derived from the share equation:

$$e_i = \frac{\mu_i}{w_i} + 1 \tag{5.9}$$

with

$$\mu_i = \frac{\partial w_i}{\partial \ln x} = \beta_i + \frac{2\lambda_i}{b(p)}\left\{\ln\left[\frac{x}{a(p)}\right]\right\} \tag{5.10}$$

The uncompensated price elasticity is given by:

$$e_{ij}^{u} = \frac{\mu_{ij}}{w_i} - \delta_{ij} \tag{5.11}$$

with

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_i} = \gamma_{ij} - \mu_i\left(\alpha_j + \sum_{k}^{n}\gamma_{jk}\ln p_k\right) - \frac{\lambda_i\beta_j}{b(p)}\left\{\ln\left[\frac{x}{a(p)}\right]\right\}^2 \tag{5.12}$$

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

$$e_{ij}^{c} = e_{ij}^{u} + e_i w_j \tag{5.13}$$

In household expenditure data, recorded zero expenditures are a common problem. The possible reasons, infrequency of purchase or corner solutions are hard to distinguish empirically however. The literature usually identifies this data issue as ”censored”, although censoring may only be a special case of the underlying data generating process. We stick to this discussion and use ”censored” as a synonym for zero observations in budget share data. Apart from the recent use of Full Information Maximum Likelihood (FIML) estimation (Chen and Yen, 2005), the suggested solutions in the literature are based on Heckman’s two step approach (Heckman, 1979). Heien and Wessells (1990) applied the two step approach to the demand context, but attracted criticism for being inconsistent in later work. Shonkwiler and Yen (1999) prove this inconsistency, showing the statistical correct way to obtain elasticity estimates in censored system settings. First, a household specific probit model is estimated with the outcome of 1 if the household consumes good i and 0 otherwise. For each household, the standard normal probability density function (pdf) ϕ and the cumulative distribution function (cdf) Φ are calculated by regressing w_i on a set of independent variables z_i. Secondly, the pdf and the cdf are integrated into the system of equations as follows:

$$w_i^* = \Phi w_i + \varphi_i \phi \tag{5.14}$$

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

Expenditure elasticity

$$e_i^* = \frac{\Phi(\mu_i)}{w_i} + 1 \tag{5.15}$$

Price elasticity

$$e_{ij}^* = \frac{\Phi(\mu_i)}{w_i} + \phi \tau_{ij}(1 - \frac{\varphi_i}{w_i}) - \delta_{ij} \tag{5.16}$$

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

5.5.2 Welfare effects

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

$$FO = \sum_{i=1}^{n} w_i \frac{\Delta p_i}{p_i^0} \tag{5.17}$$

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

$$CV = \sum_{i=1}^{n} w_i \left(\frac{\Delta p_i}{p_i^0} \right) + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} w_i e_{ij} \left(\frac{\Delta p_i}{p_i^0} \right) \left(\frac{\Delta p_j}{p_j^0} \right) \tag{5.18}$$

5.5.3 Household CO_2 emissions

CO_2 emissions embodied in household consumption (carbon footprints) could easily be calculated with direct carbon intensities measured in available physical energy units (e.g. 2.4 kg CO_2 per liter gasoline). However, the direct carbon content is not accounting for emissions in the production process (e.g. refining gasoline) and for electricity and the residual other goods category we would not be able to provide carbon contents. Therefore, in our analytical framework, carbon emissions are calculated from a demand side perspective by employing an input-output (IO) model. These carbon footprints are derived by calculating carbon intensities of the Indonesian production sectors and a subsequent matching with household consumption. The underlying database is the national IO table and CO_2 emissions per industrial sector from the World Input Output Database (Timmer et al., 2015).[9] Total production emissions C_{ind} are simply a product of the matrix of sector specific direct carbon intensities CI and total production vector x:

$$CI'x = C_{ind} \tag{5.19}$$

[9]The matching between WIOD sectors and the SUSENAS cinsumption classfication is documented in table D.1, Appendix.

Since our analysis has a focus on final demand y, direct carbon intensities are not of interest and we transform equation (5.19) with the Leontief inverse $(I-A)^{-1}$. Recalling total production

$$x = (I-A)^{-1}y \tag{5.20}$$

and substituting (5.20) for x in (5.19) gives us total production emissions from a demand side perspective:

$$CI'(I-A)^{-1}y = C_{ind} \tag{5.21}$$

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

$$CI_{ind} = CI'(I-A)^{-1} \tag{5.22}$$

which we use in the further analysis. For the fuels gasoline, kerosene and LPG we have to additionally add these production based emissions to the direct carbon content emitted in the combustion process.[10] These direct carbon contents are transformed to household specific expenditure based carbon intensities by calculating direct carbon emissions (quantities multiplied with carbon contents) and dividing through the respective fuel expenditures. Household specific carbon footprints are then calculated by multiplying expenditures per good with the respective carbon intensity CI_k (tCO_2/MXN):

$$CO_{2i} = \sum_{k=1}^{5} (exp_{ik} * CI_k) \tag{5.23}$$

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

$$w_i^1 = \Phi\left(\widehat{\alpha_i} + \sum_{j=1}^{n} \widehat{\gamma_{ij}} \ln p_j^1 + \widehat{\beta_i} \ln\left[\frac{x^0}{a(p^1)}\right] + \frac{\widehat{\lambda_i}}{b(p^1)}\left\{\ln\left[\frac{x^0}{a(p^1)}\right]\right\}^2\right) + \varphi_i\phi + \widehat{\varepsilon_i}^0 \tag{5.24}$$

The carbon emissions per household are then calculated as:

$$CO_2^1 = \sum_{i=1}^{n}\left(\frac{exp_i^1}{1+\frac{\Delta p_i}{p_i^0}} * CI_i\right) \tag{5.25}$$

[10] Gasoline: 2.31 kg CO_2/l, Kerosene: 2.55 kg CO_2/l, LPG: 1.5 kg CO_2/kg

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

5.6 Energy price changes, poverty, welfare effects and CO_2 emissions

We simulate the welfare and energy poverty impact for two stylized scenarios (20 and 50 percent price increase) and obtain results for single and multiple simultaneous price changes. Based on the current low international oil prices, scenarios with even higher price increases up to 100 percent and above are indeed possible for the coming years considering past trends. Yet, price changes of this magnitude imply that we would have to forecast completely out of sample. As mentioned before, the survey data offers price information for electricity, gasoline, kerosene and LPG. Unfortunately we neither have price information for other transport nor firewood expenditures and have to exclude them from further analysis. In addition to these scenarios with energy price increases, we also simulate a scenario that interprets the price change as an ad valorem tax rate and redistributes collected tax revenues via lump-sum cash transfers to households. We assume similarity between consumers' responses of price changes through market mechanisms and taxes, although there is increasing evidence questioning this assumption (Rivers and Schaufele, 2015; Tiezzi and Verde, 2016). Since this difference is most likely to play out in the long-run, our analysis still offers valid results in the short-run.

5.6.1 Estimation results

The first stage estimation generates results from the probit model specification. Marginal effects, evaluated at the sample means are displayed in table 5.3. All energy-price coefficients have close to zero magnitude which implies that energy prices appear not to be a major determinant of energy use decisions. Income on the other hand is an important factor, particularly for private motorized transport. In the next step, the full demand system is estimated. Due to the difficult economic interpreation of model coefficients, we report expenditure elasticities in table 5.4 and price elasticities in table 5.5. Following Banks et al. (1997), we calculate elasticities for each household individually and construct a weighted average, with the weights generated as the household's share of total sample expenditure for the relevant good.

With rising income, the willingness to spend more on electricity increases, turning from a necessity to a luxury good at the 90th percentile. We observe high income responses towards gasoline use, with slightly rising budget elasticities over the expenditure distribution all above one. Gasoline is clearly a luxury good for households of all incomes. Kerosene also exhibits budget elasticities close to 1, particularly for lower income households. LPG is also estimated to be a necessity for all households, although as in the case of kerosene, the tendency to demand more quantity declines with rising income.

Table 5.3 First stage probit model (marginal effects at means)

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

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

Households with different income respond quite similarly to price changes for all energy items, which is why we show only one price elasticity matrices for the first, fifth and tenth expenditure per capita decile. In general, households react strongly to price changes for all energy items. Most own-price elasticities are close to -1 with the strongest response observed for gasoline. Based on the estimations, we expect to find differences between first and second order welfare effects particularly for electricity and gasoline price changes when high usage rates meet relatively large own-price elasticities.

Table 5.4 Budget elasticities

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

Standard errors in parentheses

The evaluation of cross-price elasticities reveals that not all modern domestic energy items are complements. Electricity and kerosene are weak substitutes while electricity and LPG are weak complements, more so for households with higher income. The cross-price elasticities between LPG and kerosene are zero, which clearly shows an unimportant role of energy prices for the politically supported conversion from kerosene to LPG. Substitution between private transport in the form of gasoline demand and domestic energy has no general pattern either. Kerosene and LPG are weak substitutes and complements with gasoline respectively while gasoline and electricity-gasoline cross-price elasticities are close to zero.

Table 5.5 Price elasticities

decile	item	price				
		Electricity	Gasoline	Kerosene	LPG	Other
1	Electricity	**-0.83**	0.03	0.01	-0.05	0.85
		(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
	Gasoline	0.03	**-1.01**	0.02	-0.03	0.96
		(0.001)	(0.003)	(0.001)	(0.002)	(0.003)
	Kerosene	0.03	0.05	**-0.95**	0.00	0.78
		(0.001)	(0.004)	(0.001)	(0.000)	(0.004)
	LPG	-0.10	-0.08	0.00	**-0.99**	1.20
		(0.004)	(0.005)	(0.000)	(0.001)	(0.008)
	Other	0.02	0.01	0.01	0.01	**-0.02**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
5	Electricity	**-0.82**	0.04	0.01	-0.09	0.83
		(0.001)	(0.000)	(0.000)	(0.002)	(0.001)
	Gasoline	0.03	**-1.03**	0.03	-0.08	0.97
		(0.000)	(0.002)	(0.001)	(0.002)	(0.002)
	Kerosene	0.04	0.14	**-0.95**	0.00	0.77
		(0.001)	(0.005)	(0.001)	(0.000)	(0.004)
	LPG	-0.16	-0.20	0.00	**-1.01**	1.33
		(0.002)	(0.004)	(0.000)	(0.001)	(0.006)
	Other	0.02	0.03	0.00	0.02	**-0.05**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
10	Electricity	**-0.80**	0.01	0.01	-0.13	0.83
		(0.001)	(0.001)	(0.000)	(0.002)	(0.001)
	Gasoline	0.01	**-0.97**	0.04	-0.17	0.96
		(0.001)	(0.001)	(0.001)	(0.003)	(0.002)
	Kerosene	0.04	0.21	**-0.94**	0.00	0.76
		(0.000)	(0.006)	(0.001)	(0.000)	(0.004)
	LPG	-0.45	-0.75	0.00	**-1.05**	2.09
		(0.005)	(0.010)	(0.000)	(0.001)	(0.013)
	Other	0.03	0.04	0.00	0.02	**-0.05**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Standard errors in parentheses

For other countries, the substitutability of energy items appears to be very context specific as finding in the empirical literature demonstrate. Tiezzi and Verde (2016) find complementarity between electricity and gasoline for the US while Nikodinoska and Schröder (2016)) find the opposite for Germany.

Since this is a critical step in the further analysis, we test for the potential bias of different prices through the geographical location of the household by including province fixed effects and find no significant difference.[11]

5.6.2 Welfare and poverty effects

A relatively moderate 20 percent price increase for all four energy items under consideration and averaging over all households per expenditure percentile is displayed in figure 5.6. As expected, electricity and gasoline make up the biggest part of the welfare losses with a progressive pattern in both cases. The relative welfare losses for a uniform 20 percent electricity price increase are between 0.4 and 0.6 percent of total expenditures for the poorest and richest households respectively. For gasoline, these relative welfare losses are larger in particular for richer households, between 0.4 and 0.7 percent. Smaller welfare effects for Kerosene and LPG reflect their relatively low usage rates and budget shares. For the domestically used LPG, a price increase would be slightly regressive, but the magnitude is small due to still low usage rates. This however could change when more and more households use LPG instead of firewood also in rural areas. The difference between the upper bound first order and the lower bound second order effects is relatively small at this magnitude of price effects. First order estimates of welfare losses in the first scenario are on average 10 percent higher. It becomes more pronounced in the second scenario of a 50 percent price increase, where the difference increases to over 20 percent for electricity and gasoline with again small observed differences for kerosene and LPG (figure 5.7). In particular for gasoline, second order effects are slightly less progressive. Responsible for this effect is not a variation of demand responses with rising expenditures but the increase in the usage rate. A larger fraction of households with actual gasoline demand also implies a larger substitution potential. Low income households which are close to the poverty line and dependent on the use of modern energy are less well represented in these average effects.

[11] Households in more remote locations face higher prices for all modern energy items and also have smaller demand.

Table 5.6 FGT poverty indices (in %), changes from baseline (Scenario I&II)

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

Table 5.7 FGT poverty indices (in %), changes from baseline (Scenario I&II + lump-sum transfer)

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

In this regard, the poverty indicators in table 5.6 do not show a large increase, but absolute numbers are important to consider.[12] The moderate electricity price increases in Scenario I raise the national poverty rate by 0.23 percent, which appears to be very small but absolutely about half a million people will be additionally classified as poor, most of them in rural areas. For gasoline price increases, we observe a similar magnitude. Although the poverty effects are relatively small due to low usage rates and budget shares of modern energy, there is a significant and growing number of households which are negatively affected by price increases. Most of these households are living in urban areas but with more rural households using modern energy items and private transport vehicles this finding is unlikely to be stable over time. Non-negligible effects can also be found for LPG price increases, which demonstrates its importance as the new major cooking fuel for Indonesian households.

In the multiple price change scenario, changing prices for all four energy items simultaneously, we observe a general progressive pattern, dominated by electricity and in particular gasoline (Figure 5.8). Nevertheless, multiple price changes for the energy items under consideration would result in serious welfare losses for poor households of close to 1.5 and 3 percent of total expenditures for scenario I and II respectively. In particular for Scenario II, higher usage rates and associated substitution options for higher income households turn the distributional effect less progressive. On the other hand, it also means there is less need to redistribute tax revenue to higher income households since they are capable of dealing with price increases. In Scenario II, poverty effects are quite strong with increases of 0.6 and 1.2 percentage points in the poverty rate for Scenario I and II respectively.

To shed some light on potential effects through redistribution if energy taxes of 20 percent are the drivers behind the price increases, we simulate a full redistribution of tax revenues via lump-sum transfers to households. For all four energy items, redistribution of tax revenue leads to welfare gains for low income households (figure 5.9). Electricity and gasoline taxes raise substantial revenue that could lead to quite large welfare gains for the majority of the population if proper redistribution schemes can be identified. Welfare gains are also reflected in poverty indicators, which improve for all scenarios (table 5.7). As much as urban households are disproportionately hit by energy price hikes, there are also more urban households which benefit from transfer payments. Since universal lump-sum transfers are unlikely to be implemented, more realistic redistribution schemes would rely on social welfare programs, which directly target the poor.[13]

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

[13] The survey data does offer information on social welfare programs but unfortunately their coverage is low and therefore unsuitable for a large scale redistribution scheme.

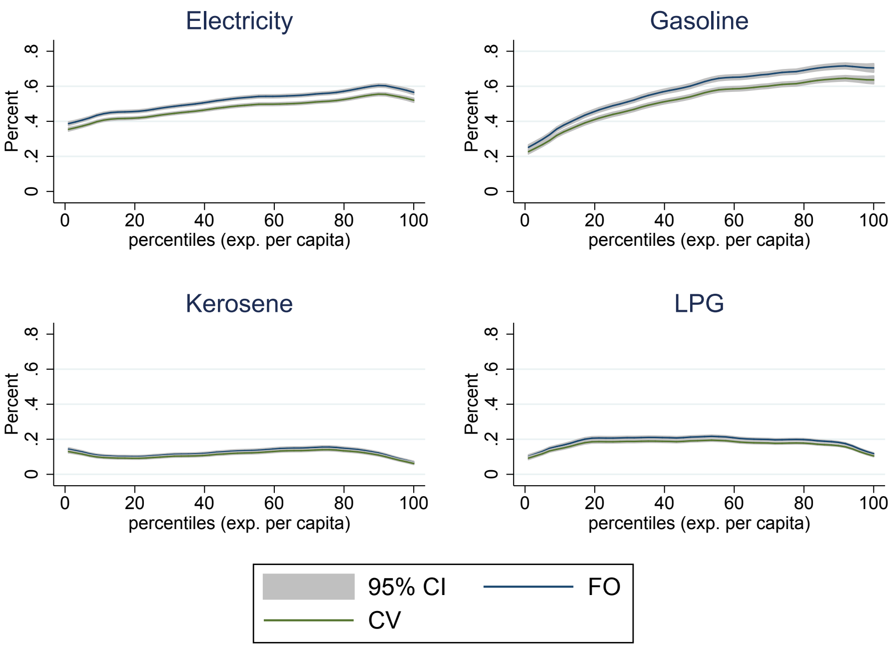

Fig. 5.6 Welfare effects Scenario I

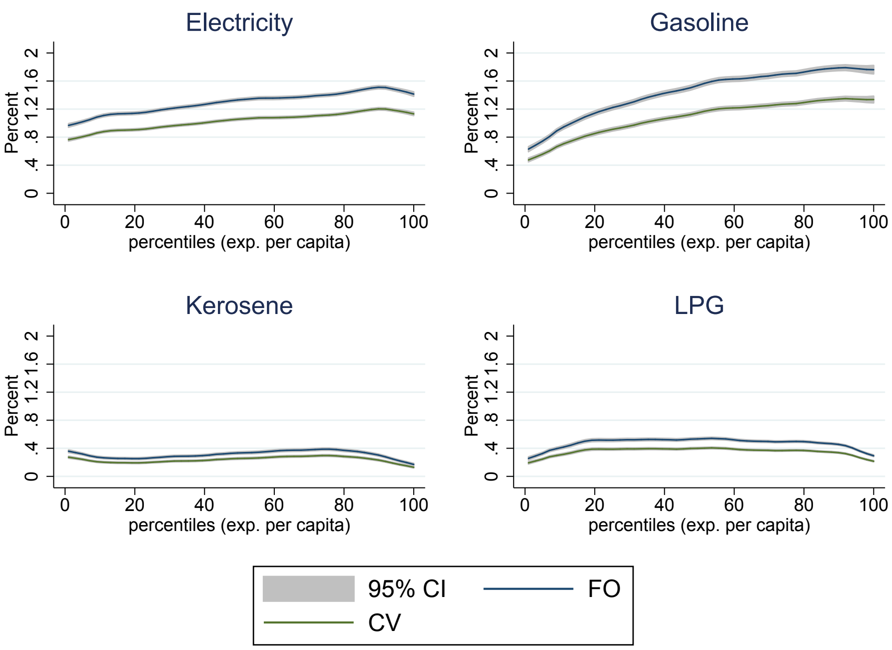

Fig. 5.7 Welfare effects Scenario II

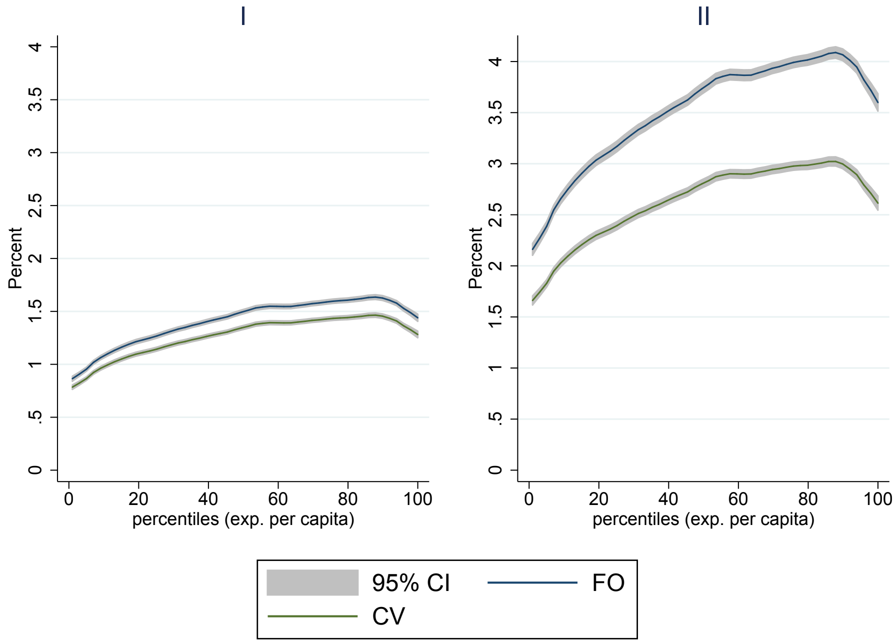

Fig. 5.8 Welfare effects simultaneous increase Scenarios I & II

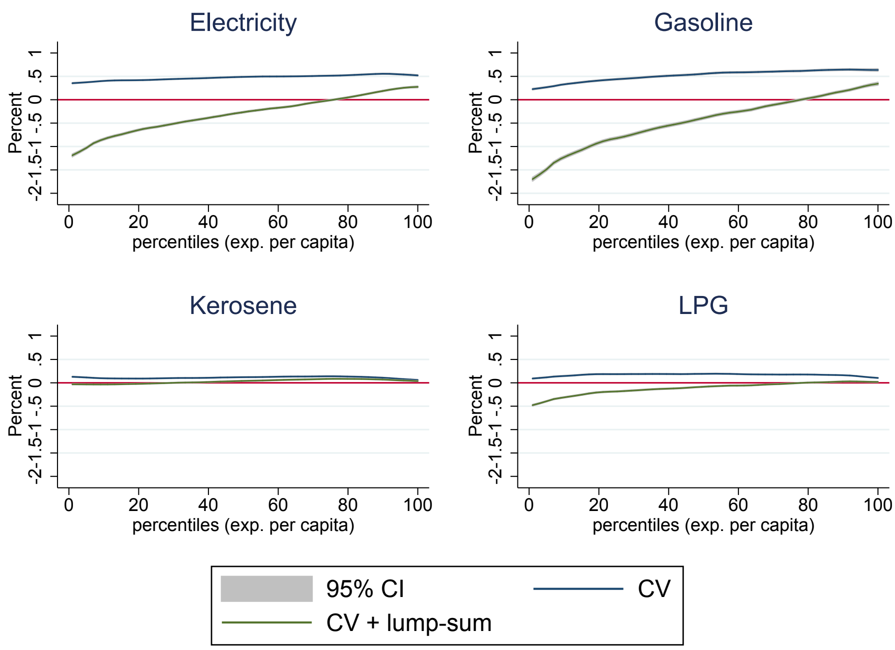

Fig. 5.9 Welfare effects with lump-sum transfers Scenario I

5.6.3 Energy poverty

Based on the estimated price elasticity matrices, we calculate the quantities households reduce per capita in response to price increases for the respective scenarios. Based on these behavioral responses, we calculate the FGT class of indices for both scenarios and energy poverty lines and find significant effects on energy poverty resulting from lower energy use. Table 5.8 displays the change in FGT indicators for the two simulated scenarios. We find considerable effects of price increases on the poverty rate with particularly tremendous effects of electricity and LPG price increases. LPG price increases result in higher energy poverty levels than kerosene price increases, the latter with the expected smallest effects. For all modern fuels, the increase in energy poverty is larger in rural areas despite the higher urban usage rates. As discussed in the interpretation of estimated price elasticities, complementarity between LPG and gasoline implies reduced domestic energy use also in the case of gasoline price increases. Energy poverty increases due to gasoline price changes are about 25 percent of LPG price increase induced energy poverty, a value close to the estimated cross-price elasticity. Redistribution of tax revenues does not change energy poverty significantly since households are projected to spend most of the extra income on other goods than energy.[14]

These findings reflect the downside of consumer responses and associated smaller calculated welfare effects through substitution. While the microeconomic welfare metric tells us only about utility based monetary effects, other welfare dimensions such as energy poverty are not directly addressed in a standard welfare assessment. Although one could argue that households take energy requirements into account in consumption decisions, they are also likely to substitute modern for traditional fuels when prices rise. Additionally, they may not internalize all associated external costs such as health issues caused by air pollution. Unfortunately, our data does not permit us to quantify the exact nature of substitution between modern and traditional fuels when prices change. However, a simple estimation of firewood demand in a Working-Leser form (Leser, 1963; Working, 1943), depending on prices of modern energy, household total expenditures x and household characteristics H sheds some light on this issue:

$$w_{fwd} = \alpha_{fwd} + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + ln(x) + H \tag{5.26}$$

Due to a significant share of zero firewood budget shares, equation (5.26) is estimated as a heckman selection model with additional variables reflecting lighting and cooking fuel choice

[14] Results are almost identical to the scenario without redistribution and therefore not reported.

Table 5.8 FGT energy poverty indices (in %), changes from baseline (Scenario I)

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

Table 5.9 FGT energy poverty indices (in %), changes from baseline (Scenario II)

		National			Rural			Urban		
		FGT (in %) - difference to baseline								
price increase	energy poverty line	0	1	2	0	1	2	0	1	2
Electricity	EPL 1	9.41	6.58	4.89	6.44	6.32	5.38	13.35	6.93	4.25
	EPL 2	6.83	3.59	2.34	7.58	4.65	3.19	5.85	2.19	1.22
Gasoline	EPL 1	2.41	1.03	0.42	0.88	0.24	-0.12	4.44	2.07	1.13
	EPL 2	0.68	-0.12	-0.24	0.04	-0.48	-0.52	1.54	0.37	0.14
Kerosene	EPL 1	1.89	1.48	1.26	1.97	2.04	1.92	1.77	0.73	0.39
	EPL 2	1.62	1.13	0.85	2.51	1.88	1.44	0.45	0.14	0.06
LPG	EPL 1	7.84	5.42	3.85	5.59	5.00	4.01	10.81	5.98	3.63
	EPL 2	5.36	2.49	1.58	5.61	3.10	2.11	5.03	1.67	0.88

in the identifying equation.[15] The estimated firewood cross-price elasticities (table 5.10) exhibit an expected substitutability between other domestically used energy items electricity, kerosene, LPG and firewood. This serves as some evidence, although not integrated into the rest of the analysis due to data constraints, that households are very likely to increase the use of traditional fuels when prices of modern, domestically used energy items rise. Households may not reduce domestically used energy as strong as energy poverty indices suggest, but instead move towards traditional fuels.

Table 5.10 Firewood cross-price elasticities

	prices			
	Electricity	Gasoline	Kerosene	LPG
firewood	0.11	-2.29	0.41	0.28

5.6.4 CO_2 emission effects

Since households respond to price changes, the effect on household related carbon emissions are expected to be negative with the estimated price elasticities. How large this effect is for the single energy items can be seen in table 5.11. The elasticity of household carbon emissions relative to price changes is the highest for electricity and gasoline due to the high carbon intensity of electricity and high budget shares for gasoline. Moderate price changes of 20 percent for electricity and gasoline lead to already substantial emission reductions at the order of 4.7 and 5.4 percent of household carbon emissions. Redistribution of tax revenues does not change this picture tremendously with on average 10 percent lower reductions, although absolute reductions will decline with the size of the price change and redistributive transfers.

Although these emission reductions appear to be rather large, they have to be put into perspective. They cannot be readily compared to domestic production based emissions, which are about 25 percent larger as demand side emissions.[16] Household emissions are in turn only 65 percent of demand side emissions, which includes imported emissions under the domestic technology assumption.[17] Relative to total production CO_2 emissions, households

[15] As in the case of demand system coefficients we do not report results due to the difficult economic interpretation and report elasticities instead.

[16] Domestic demand emissions (including imports) are only 80 percent of domestic production emissions, the rest gets exported.

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

are responsible for about 50 percent. Additionally, the household survey covers only about 50 percent of demand emissions calculated with the IO data. How to finally interpret the emission reductions is a question of how to deal with the large disparity between survey and IO data. If the survey data is scaled up to match the total aggregate consumption in the IO tables, the calculated relative reductions of household emissions remain identical. Relative to total domestic, production based CO_2 emissions, the estimated reductions need to be adjusted downwards by 50 percent if the survey data is scaled or 75 percent when it remains unscaled.

Table 5.11 Household CO_2-price elasticities

Scenario	electricity	gasoline	kerosene	LPG	energy
price increase	-0.238	-0.272	0.022	-0.141	-0.612
price increase + lump-sum	-0.214	-0.243	0.024	-0.133	-0.555

5.7 Conclusion

Consumer energy price increases affect richer households more in relative and consequentially also in absolute terms. On the one hand, our findings confirm prior studies, which are based on observed demand and the assumption of zero substitution between goods, on the progressive direction of this effect for electricity and gasoline. On the other hand, we find neutral effects for Kerosene and LPG and smaller welfare losses for electricity and gasoline by employing second-order welfare estimates. The calculated first-order effects for electricity and gasoline are on average 10 and 20 percent larger in Scenario I and II, which may seem small in relative terms but are substantial differences in absolute terms. First-order effects particularly overestimate welfare losses for the upper part of the income distribution where small percentage changes in relative terms translate into large absolute monetary amounts. For redistribution this has important consequences, since richer households are estimated to be capable of dealing with increasing energy prices and therefore need less compensation. This holds particularly for gasoline, which is at the center of the subsidy debate and a major fuel used by households. Due to lower usage rates for low income households, also the poverty impacts are moderate when prices change by small amounts. Despite these supposedly small relative changes, a non-marginal number of low income households are actually highly affected by energy price changes. Additionally, there is a large and growing number of households who are vulnerable to large energy price increases, which appear to be quite possible when energy subsidies are completely abolished.

Eventually, redistribution of taxes or saved subsidies is crucial of turning this story around into welfare gains and poverty reduction. Although the simulated lump-sum transfers are already quite effective in absorbing large welfare shocks, more targeted transfers are certainly desirable from an equity and fiscal perspective. Although the estimation of a demand system proves to be already useful for calculating welfare effects, the consideration of energy poverty and household related carbon emissions makes it additionally valuable. Without changes in quantities demanded, energy poverty would not change in our expenditure based definition of energy poverty. Additionally to welfare losses from energy price increases, households also suffer from a lack of modern energy items which could trigger additional negative impacts such as adverse health effects through the shift to traditional sources of energy. By simulating energy item quantities, we find substantial effects of price increases for energy used domestically on energy poverty. Somewhat surprisingly, this also holds for gasoline since the estimation reveals a complementary relationship to LPG. Particularly problematic for energy poverty is this complementarity for low income households, for which these energy goods have much more of a necessity character than for high income households. The resulting divergence of relatively small estimated second order welfare effects and large impacts on energy poverty reflects a weakness of standard welfare metrics which assumes complete information and the absence of negative externalities. Also redistribution of tax revenue is only partially able to deal with rising energy poverty in our model since households spend most of the transfer income on other goods than modern energy. The resulting increased use of traditional biomass fuels such as firewood is certainly critical from both a health perspective through indoor air pollution and a CO_2 emission perspective through deforestation.

The reduction of carbon emissions embodied in household consumption is the flip side of the coin to energy poverty increases and welfare losses. The pricing of direct energy use by households leads to substantial emissions reductions at the order of 0.28 percent for each percent increase in prices for gasoline or electricity. Analog to the results for energy poverty, where households only partially increase their energy use due to redistributive transfers, the adverse emission effect of redistribution is very limited with 10 percent smaller reductions. These emission reductions are, as is the nature of our data and model, exclusively embodied in household consumption. When comparing to production based CO_2 emissions, which are usually referred to in other studies, the effects are about half of what is estimated. For all simulated effects, we have to keep in mind that households can only reduce energy use to a certain minimum level. This and the nature of our modeling framework restricts the interpretation of results to the very short run perspective.

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Appendix A

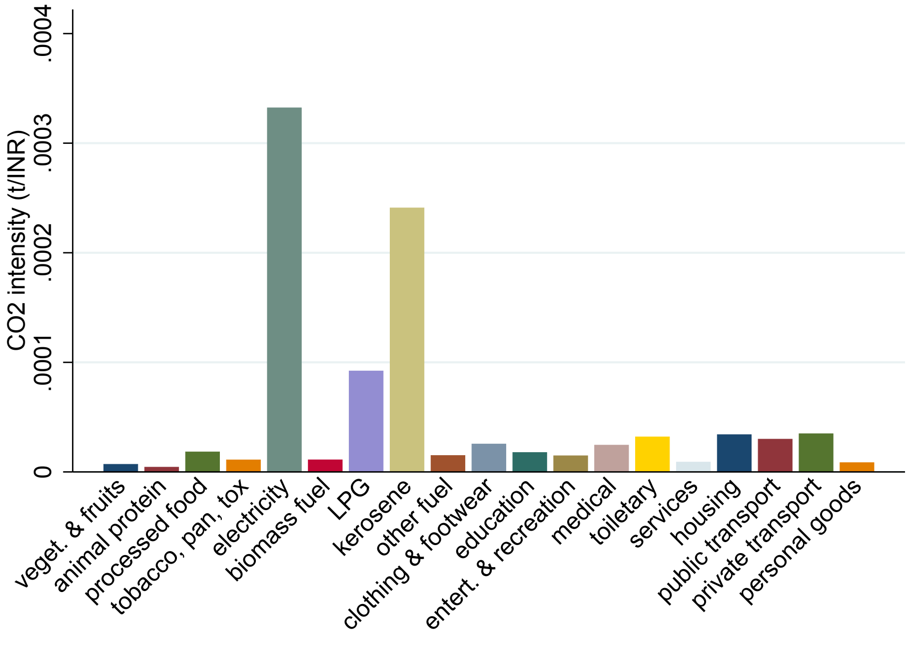

Fig. A.1 Emission Intensities of Expenditure Sub-Groups (2004/05)

Table A.1 NSS-CSO Matching 2011/12

NSS code	NSS description	IO code	Exp group code
101	rice – PDS	1	1
102	rice – other sources	1	1
103	chira	1	1
104	khoi, lawa	1	1
105	muri	1	1
106	other rice products	1	1
107	wheat/ atta – PDS	2	1
108	wheat/ atta – other sources	2	1
110	maida	2	1
111	suji, rawa	2	1
112	sewai, noodles	1	1
113	bread (bakery)	2	1
114	other wheat products	2	1
115	jowar & its products	3	1
116	bajra & its products	4	1
117	maize & products	5	1
118	barley & its products	2	1
120	small millets & their products	4	1
121	ragi & its products	7	1
122	other cereals	20	1
129	**cereal: sub-total (101-122)**		
139	cereal substitutes: tapioca, etc.	20	1
140	arhar, tur	6	1
141	gram: split	6	1
142	gram: whole	6	1
143	moong	6	1
144	masur	6	1
145	urd	6	1
146	peas	6	1
147	khesari	7	1
148	other pulses	7	1
150	gram products	6	1
151	besan	6	1
152	other pulse products	7	1
159	**pulses & pulse products: s.t. (140-152)**		
160	milk: liquid (litre)	21	2
161	baby food	21	2
162	milk: condensed/ powder	21	2
163	curd	21	2
164	ghee	21	2

NSS code	NSS description	IO code	Exp group code
165	butter	21	2
166	ice-cream	21	2
167	other milk products	21	2
169	**milk & milk products: s.t.(160-167)**		
170	salt	37	1
171	sugar - PDS	38	1
172	sugar - other sources	38	1
173	gur	8	1
174	candy, misri	39	1
175	honey	38	1
179	**sugar & salt: s.t. (170-175)**		
180	vanaspati, margarine	40	1
181	mustard oil	11	1
182	groundnut oil	9	1
183	coconut oil	10	1
184	refined oil	10	1
185	soyabean, saffola, etc.]	41	1
189	**edible oil: s.t. (180-185)**		
190	eggs (no.)	23	2
191	fish, prawn	26	2
192	goat meat/mutton	22	2
193	beef/ buffalo meat	22	2
194	pork	22	2
195	chicken	23	2
196	others: birds, crab, oyster, tortoise, etc.	23	2
199	**egg, fish & meat: s.t. (190-199)**		
200	potato	19	1
201	onion	19	1
202	tomato	19	1
203	brinjal	19	1
204	radish	19	1
205	carrot	19	1
206	palak/other leafy vegetables	19	1
207	chillis: green	19	1
208	lady's finger	19	1
210	parwal, patal	19	1
211	cauliflower	19	1
212	cabbage	19	1
213	pumpkin	19	1
214	peas	19	1
215	french beans, barbati	19	1
216	lemon (no.)	18	1

NSS code	NSS description	IO code	Exp group code
217	other vegetables	19	1
219	**vegetables: s.t. (200-217)**		
220	banana (no.)	18	1
221	jackfruit	18	1
222	watermelon	18	1
223	pineapple (no.)	18	1
224	coconut (no.)	18	1
225	coconut green (no.)	18	1
226	guava	18	1
227	singara	18	1
228	orange, mausami (no.)	18	1
230	papaya	18	1
231	mango	18	1
232	kharbooza	18	1
233	pears/naspati	18	1
234	berries	18	1
235	leechi	18	1
236	apple	18	1
237	grapes	18	1
238	other fresh fruits	18	1
239	**fruits (fresh): s.t.(250-268)**		
240	coconut: copra	10	1
241	groundnut	9	1
242	dates	18	1
243	cashewnut	9	1
244	walnut	9	1
245	other nuts	9	1
246	raisin, kishmish, monacca, etc.	18	1
247	other dry fruits	18	1
249	**fruits (dry): s.t. (270-277)**		
250	ginger (gm)	20	1
251	garlic (gm)	20	1
252	jeera(gm)	20	1
253	dhania (gm)	20	1
254	turmeric (gm)	20	1
255	black pepper (gm)	20	1
256	dry chillies (gm)	20	1
257	tamarind (gm)	20	1
258	curry powder (gm)	20	1
260	oilseeds (gm)	20	1
261	other spices (gm)	20	1
269	**spices: s.t. (250-269)**		

NSS code	NSS description	IO code	Exp group code
270	tea : cups (no.)	42	3
271	tea : leaf (gm)	14	3
272	coffee : cups (no.)	42	3
273	coffee: powder (gm)	15	3
274	mineral water (litre)	44	3
275	cold beverages: bottled/canned (litre)	44	3
276	fruit juice and shake (litre)	44	3
277	other beverages: cocoa, chocolate, etc.	44	3
279	**beverages: sub-total (270-279)**		
280	cooked meals purchased (no.)	43	3
281	cooked meals received free in workplace** (no.)	43	3
282	cooked meals received as assistance ** (no.)	43	3
283	cooked snacks purchased	43	3
284	other served processed food	43	3
289	**served processed food.: sub-total (280-284)**		
290	prepared sweets	43	3
291	biscuits	43	3
292	papad, bhujia, namkeen, mixture,	43	3
293	chips (gm)	43	3
294	pickles (gm)	43	3
295	sauce, jam, jelly (gm)	43	3
296	other packaged processed food		
299	**packaged processed food: sub-total (290-296)**		
300	pan: leaf (no.)	17	4
301	pan: finished (no.)	45	4
302	ingredients for pan (gm)	45	4
309	**pan: s.t. (300-302)**		
310	bidi (no.)	45	4
311	cigarettes (no.)	45	4
312	leaf tobacco (gm)	17	4
313	snuff (gm)	45	4
314	hookah tobacco (gm)	45	4
315	cheroot (no.)	45	4
316	zarda, kimam, surti (gm)	45	4
317	other tobacco products	45	4
319	**tobacco: s.t. (310-317)**		
320	ganja (gm)	44	4
321	toddy (litre)	44	4
322	country liquor (litre)	44	4
323	beer (litre)	44	4
324	foreign/refined liquor or wine (litre)	44	4
325	other intoxicants	44	4

NSS code	NSS description	IO code	Exp group code
329	**intoxicants: s.t. (320-325)**		
330	coke	64	9
331	firewood and chips	56	6
332	electricity (std. unit)	107	5
333	dung cake	24	6
334	kerosene – PDS (litre)	63	8
335	kerosene – other sources (litre)	63	8
336	matches (box)	56	9
337	coal	64	9
338	LPG [excl. conveyance]	63	7
340	charcoal	64	9
341	candle (no.)	73	9
342	gobar gas	28	6
343	petrol (litre) [excl. conveyance]	63	9
344	diesel (litre) [excl. conveyance]	63	9
345	other fuel	63	9
349	**fuel and light: s.t. (330-345)**		
350	dhoti (no.)	54	10
351	sari (no.)	54	10
352	cloth for shirt, pyjama, salwar, etc. (metre)	54	10
353	cloth for coat, trousers, overcoat, etc. (metre)	54	10
354	chaddar, dupatta, shawl, etc. (no.)	54	10
355	lungi (no.)	54	10
356	school/college uniform: boys	54	10
357	school/college uniform: girls	54	10
358	kurta-pajama suits: males (no.)	54	10
360	kurta-pajama suits: females (no.)	54	10
361	kurta, kameez (no.)	54	10
362	pajamas, salwar (no.)	54	10
363	shirts, T-shirts (no.)	54	10
364	shorts, trousers, bermudas (no.)	54	10
365	frocks, skirts, etc. (no.)	54	10
366	blouse, dupatta, scarf, muffler (no.)	54	10
367	lungi (no.)	54	10
368	other casual wear*	54	10
370	baniyan, socks, other hosiery and undergarments, etc. (no.)	54	10
371	gamchha, towel, handkerchief (no.)	54	10
372	infant clothing	54	10
373	headwear, belts, ties (no.)	54	10
374	knitting wool (gm)	54	10
375	clothing (first-hand): other	54	10

NSS code	NSS description	IO code	Exp group code
376	clothing: second-hand	54	10
379	**clothing: sub-total (350-376)**		
380	bed sheet, bed cover (no.)	54	16
381	rug, blanket (no.)	52	16
382	pillow, quilt, mattress (no.)	54	16
383	cloth for upholstery, curtains, tablecloth, etc. (metre)	54	16
384	mosquito net (no.)	54	16
385	bedding: others	54	16
389	**bedding, etc.: s.t. (380-385)**		
390	leather boots, shoes	59	10
391	leather sandals, chappals, etc.	59	10
392	other leather footwear	59	10
393	rubber / PVC footwear	61	10
394	other footwear	59	10
395	footwear: second-hand	59	10
399	**footwear: sub-total (390-395)**		
400	books, journals: first hand	58	11
401	books, journals, etc.: second hand	58	11
402	newspapers, periodicals	57	11
403	library charges	121	11
404	stationery, photocopying charges	123	11
405	tuition and other fees (school, college, etc.)	121	11
406	private tutor/ coaching centre	121	11
407	educational CD	121	11
408	other educational expenses	121	11
409	**education: s.t. (400-408)**		
410	medicine	70	13
411	X-ray, ECG, pathological test, etc.	122	13
412	doctor’s/surgeon’s fee	122	13
413	hospital & nursing home charges	122	13
414	other medical expenses	122	13
419	**medical - institutional: s.t. (410-414)**		
420	medicine	70	13
421	X-ray, ECG, pathological test, etc.	122	13
422	doctor’s/ surgeon’s fee	122	13
423	family planning appliances	122	13
424	other medical expenses	122	13
429	**medical – non-institutional: sub-total (420-424)**		
430	cinema, theatre	129	12
431	mela, fair, picnic	129	12
432	sports goods, toys, etc.	105	12
433	club fees	129	12

NSS code	NSS description	IO code	Exp group code
434	goods for recreation and hobbies	105	12
435	photography	94	12
436	VCD/ DVD hire (incl. instrument)	94	12
437	cable TV	94	12
438	other entertainment	129	12
439	**entertainment: sub-total (430-438)**		
440	spectacles	105	19
441	torch	105	19
442	lock	105	19
443	umbrella, raincoat	105	19
444	lighter (bidi/ cigarette/ gas stove)	105	19
445	other minor durable-type goods	105	19
449	**minor durable-type goods: sub-total (440-445)**		
450	toilet soap	71	14
451	toothpaste, toothbrush, comb, etc.	62	14
452	powder, snow, cream, lotion and perfume	71	14
453	hair oil, shampoo, hair cream	71	14
454	shaving blades, shaving stick, razor	82	14
455	shaving cream, aftershave lotion	71	14
456	sanitary napkins	57	14
457	other toilet articles	71	14
459	**toilet articles: sub-total (450-457)**		
460	electric bulb, tubelight	91	16
461	electric batteries	90	16
462	other non-durable electric goods	91	16
463	earthenware	76	16
464	glassware	76	16
465	bucket, water bottle/ feeding bottle & other plastic goods	62	16
466	coir, rope, etc.	53	16
467	washing soap/soda/powder	71	16
468	other washing requisites	71	16
470	incense (agarbatti), room freshener	71	16
471	flower (fresh): all purposes	20	16
472	mosquito repellent, insecticide, acid etc.	68	16
473	other petty articles	76	16
479	**other household consumables: sub-total (460-473)**		
480	domestic servant/cook	123	15
481	attendant	123	15
482	sweeper	123	15
483	barber, beautician, etc.	123	15
484	washerman, laundry, ironing	123	15
485	tailor	123	15

NSS code	NSS description	IO code	Exp group code
486	grinding charges	128	15
487	telephone charges: landline*	128	15
488	telephone charges: mobile	128	15
490	postage & telegram	128	15
491	miscellaneous expenses	129	15
492	priest	128	15
493	legal expenses	125	15
494	repair charges for non-durables	129	15
495	pet animals (incl. birds, fish)	129	15
496	internet expenses	128	15
497	other consumer services excluding conveyance	129	15
499	**consumer services excluding conveyance: sub-total (480-496)**		
500	air fare	112	18
501	railway fare	109	17
502	bus/tram fare	97	17
503	taxi, auto-rickshaw fare	97	17
504	steamer, boat fare	111	17
505	rickshaw (hand drawn & cycle) fare	99	17
506	horse cart fare	22	17
507	porter charges	128	17
508	petrol for vehicle	29	18
510	diesel for vehicle	29	18
511	lubricants & other fuels for vehicle	29	18
512	school bus, van, etc.	97	17
513	other conveyance expenses	98	17
519	**conveyance: sub-total (500-513)**		
520	house rent, garage rent (actual)	120	16
521	hotel lodging charges	117	16
522	residential land rent	120	16
523	other consumer rent	120	16
529	**rent: sub-total (520-523)**		
539	**house rent, garage rent (imputed- urban only)**	120	16
540	water charges	108	16
541	other consumer taxes & cesses	130	15
549	**consumer taxes and cesses: sub-total (540-541)**		
550	bedstead	54	16
551	almirah, dressing table	54	16
552	chair, stool, bench, table	55	16
553	suitcase, trunk, box, handbag and other travel goods	63	16
554	foam, rubber cushion	61	16
555	carpet, daree & other floor mattings	52	16

NSS code	NSS description	IO code	Exp group code
556	paintings, drawings, engravings, etc.	69	16
557	other furniture & fixtures (couch, sofa, etc.)	55	16
559	**furniture & fixtures: sub-total (550-557)**		
560	radio, 2-in-1	94	12
561	television	94	12
562	VCR/VCD/DVD player	94	12
563	camera & photographic equipment	94	12
564	CD, DVD, audio/video cassette, etc	94	12
565	musical instruments	105	12
566	other goods for recreation	105	12
569	**goods for recreation: sub-total (560-566)**		
570	stainless steel utensils	82	16
571	other metal utensils	82	16
572	casseroles, thermos, thermoware	82	16
573	other crockery & utensils	82	16
579	**crockery & utensils: sub-total (570-573)**		
580	electric fan	91	16
581	air conditioner, air cooler	91	16
582	inverter	91	16
583	lantern, lamp, electric lampshade	91	16
584	sewing machine	91	16
585	washing machine	91	16
586	stove	91	16
587	pressure cooker/ pressure pan	91	16
588	refrigerator	91	16
590	water purifier	91	16
591	electric iron, heater, toaster, oven & other electric heating appliances	91	16
592	other cooking/ household appliances	91	16
599	**cooking & other household appliances: sub-total (580-592)**		
600	bicycle	99	18
601	motor cycle, scooter	98	18
602	motor car, jeep	97	18
603	tyres & tubes	61	18
604	other transport equipment	100	18
609	**personal transport equipment: sub-total (600-604)**		
610	contact lenses, hearing aids & orthopaedic equipment	102	13
611	other medical equipment	102	13
619	**therapeutic appliances: sub-total (610-611)**		
620	clock, watch	101	19
621	other machines for household work	91	19

NSS code	NSS description	IO code	Exp group code
622	PC/ Laptop/ other peripherals incl. software	92	19
623	mobile handset	92	19
624	telephone instrument (landline)	92	19
625	any other personal goods	93	19
629	**other personal goods: sub-total (620-625)**		
630	bathroom and sanitary equipment	87	16
631	plugs, switches & other electrical fittings	89	16
632	residential building & land (cost of repairs only)	129	16
633	other durables (specify)	105	16
639	**residential building, land and other durables: sub-total (630-633)**		
640	gold ornaments	103	19
641	silver ornaments	103	19
642	jewels, pearls	103	19
643	other ornaments	103	19
649	**jewellery & ornaments: sub-total (640-643)**		
659	**durable goods: total (559+569+579+599+609+619+629+639+649)**		

Appendix B

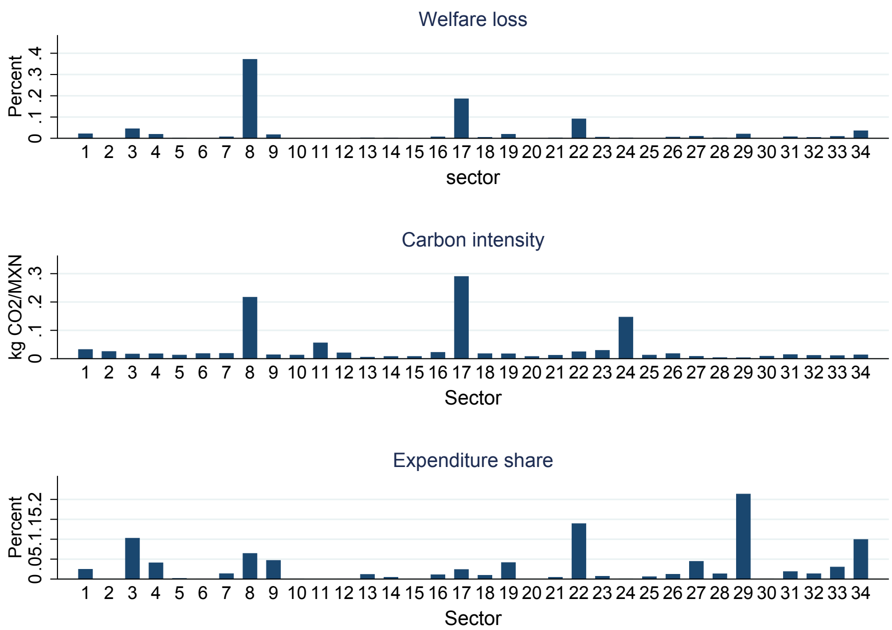

Fig. B.1 Decomposition welfare loss, top 10 percent

Table B.1 Inequality effects (Gini Index)

Scenario	National	Rural	Urban
Baseline	0.518	0.452	0.505
A			
I (USD 3.5)	0.518	0.452	0.505
II (USD 20)	0.519	0.452	0.505
II (USD 20) + lump-sum	0.516	0.449	0.503
II (USD 20) + PROSPERA	0.514	0.440	0.503
III (USD 50)	0.519	0.453	0.506
III (USD 50) + lump-sum	0.514	0.444	0.501
III (USD 50) + PROSPERA	0.509	0.425	0.501
B			
I (USD 3.5)	0.518	0.452	0.505
II (USD 20)	0.519	0.452	0.505
II (USD 20) + lump-sum	0.516	0.448	0.503
II (USD 20) + PROSPERA	0.513	0.436	0.503
III (USD 50)	0.520	0.453	0.507
III (USD 50) + lump-sum	0.513	0.442	0.500
III (USD 50) + PROSPERA	0.507	0.419	0.500
C			
I (USD 3.5)	0.518	0.452	0.505
II (USD 20)	0.519	0.454	0.506
II (USD 20) + lump-sum	0.515	0.447	0.502
II (USD 20) + PROSPERA	0.511	0.431	0.502
III (USD 50)	0.521	0.457	0.508
III (USD 50) + lump-sum	0.510	0.440	0.498
III (USD 50) + PROSPERA	0.502	0.410	0.498

Table B.2 ENIGH-WIOD Matching 2014

ENIGH code	ENIGH description	WIOD sector
A001	Maíz en grano	1
A002	Harina de maíz	3
A003	Masa de maíz	3
A004	Tortilla de maíz	3
A005	Tostadas	3
A006	Otros productos de maíz	3
A007	Harina de trigo	3
A008	Tortilla de harina	3
A009	Pasta para sopa	3
A010	Galletas dulces	3
A011	Galletas saladas	3

ENIGH code	ENIGH description	WIOD sector
A012	Pan blanco: bolillo, telera, baguete, etcétera	3
A013	Pan dulce en piezas	3
A014	Pan dulce empaquetado	3
A015	Pan para sándwich, hamburguesa, hot-dog y tostado	3
A016	Pasteles y pastelillos en piezas o a granel	3
A017	Pasteles y pastelillos empaquetados	3
A018	Otros productos de trigo	3
A019	Arroz en grano	1
A020	Otros productos de arroz	3
A021	Cereal de maíz, de trigo, de arroz, de avena, de granola, etcétera	1
A022	Botanas: frituras, palomitas, cheetos, doritos etcétera (excepto papas)	3
A023	Sopas instantáneas	3
A024	Otros cereales	1
A025	Bistec de res (de cualquier parte que se saque)	3
A026	Arrachera, filete	3
A027	Milanesa de res	3
A028	Chamorro de res	3
A029	Chuleta de costilla de res	3
A030	Agujas, aldilla, chambarete, diezmillo, espinazo, fajilla de res para asar, retazo, tampiqueña	3
A031	Cocido de res	3
A032	Cortes especiales de res	3
A033	Hamburguesas de res para asar	3
A034	Molida de res	3
A035	Pulpa de res en trozo	3
A036	Carne de otras partes de la res	3
A037	Vísceras de res	3
A038	Bistec de puerco (de cualquier parte que se saque)	3
A039	Pierna de puerco en trozo	3
A040	Pulpa de puerco en trozo	3
A041	Molida de puerco	3
A042	Costilla y chuleta de puerco	3
A043	Espaldilla de puerco	3
A044	Codillo de puerco	3
A045	Carne de otras partes del puerco	3
A046	Vísceras de puerco	3
A047	Carne enchilada	3
A048	Chicharrón de puerco	3
A049	Chorizo con cualquier condimento y color y longaniza	3
A050	Chuleta ahumada de puerco	3
A051	Machaca y carne seca	3
A052	Jamón de puerco	3

ENIGH code	ENIGH description	WIOD sector
A053	Mortadela, queso de puerco y salami, bolonia de carnes surtidas	3
A054	Lardo procesado (tocino)	3
A055	Salchichas y salchichón	3
A056	Otras carnes procesadas	3
A057	Pierna, muslo o pechuga de pollo con hueso	3
A058	Pierna, muslo o pechuga de pollo sin hueso	3
A059	Pollo entero o en piezas excepto, pierna, muslo y pechuga	3
A060	Vísceras y otras partes del pollo	3
A061	Otras aves	3
A062	Chorizo de pollo, jamón y nugget, salchicha, mortadela, etcétera	3
A063	Borrego: carnero y borrego	3
A064	Chivo y cabrito	3
A065	Otras carnes: caballo, conejo, iguana, jabalí, rana, tortuga, venado	3
A066	Pescado entero limpio y sin limpiar	3
A067	Filete de pescado	3
A068	Atún enlatado	3
A069	Salmón y bacalao procesado	3
A070	Pescado ahumado, seco, nugget, sardina, etcétera	3
A071	Anguilas, angulas, hueva de pescado, mantarraya, pejelagarto, etcétera	3
A072	Camarón fresco	3
A073	Mariscos frescos	3
A074	Mariscos procesados	3
A075	Leche pasteurizada de vaca	3
A076	Leche condensada	3
A077	Leche evaporada	3
A078	Leche en polvo entera o descremada	3
A079	Leche modificada o maternizada	3
A080	Leche no pasteurizada (leche bronca)	3
A081	Otras leches: de burra, de cabra, de soya	3
A082	Queso amarillo en rebanadas o para untar	3
A083	Queso añejo y cotija	3
A084	Queso chihuahua	3
A085	Queso fresco	3
A086	Queso manchego	3
A087	Queso oaxaca o asadero	3
A088	Otros quesos	3
A089	Crema	3
A090	Mantequilla	3
A091	Bebidas fermentadas de leche	3
A092	Otros derivados de la leche	3
A093	Huevo de gallina blanco y rojo	3
A094	Otros huevos: codorniz, pata, pava etcétera	3

ENIGH code	ENIGH description	WIOD sector
A095	Aceite vegetal: canola, cártamo, girasol, maíz, etcétera	3
A096	Aceite de coco, oliva, soya	3
A097	Margarina	3
A098	Manteca de puerco	3
A099	Manteca vegetal	3
A100	Otros aceites: de bacalao, de tiburón, de tortuga, enjundia	3
A101	Betabel y camote	1
A102	Papa	1
A103	Rábano	1
A104	Otros tubérculos	1
A105	Harina para puré de papa	3
A106	Papas fritas en bolsa o a granel	3
A107	Acelgas, espinacas y verdolagas	1
A108	Aguacate	1
A109	Ajo	1
A110	Brócoli	1
A111	Calabacita y calabaza	1
A112	Cebolla	1
A113	Chayote	1
A114	Chícharo	1
A115	Chile jalapeño	1
A116	Chile poblano	1
A117	Chile serrano	1
A118	Otros chiles	1
A119	Cilantro	1
A120	Col y repollo	1
A121	Ejote	1
A122	Elote	1
A123	Epazote	1
A124	Jitomate	1
A125	Lechuga	1
A126	Nopal	1
A127	Pepino	1
A128	Perejil y yerbabuena	1
A129	Tomate verde	1
A130	Zanahoria	1
A131	Otras verduras	1
A132	Germinados de maíz, de soya, de trigo	1
A133	Chiles envasados	3
A134	Chile secos o en polvo	3
A135	Verduras y legumbres envasadas	3
A136	Verduras y legumbres congeladas	3

ENIGH code	ENIGH description	WIOD sector
A137	Frijol en grano	1
A138	Garbanzo en grano	1
A139	Haba amarilla o verde en grano	1
A140	Lenteja en grano	1
A141	Otras leguminosas en grano	1
A142	Frijol procesado	3
A143	Otras leguminosas procesadas	3
A144	Semillas a granel	1
A145	Semillas envasadas	1
A146	Semillas procesadas	1
A147	Anona, chirimoya, guanábana	1
A148	Cereza, frambuesa, fresa, zarzamora	1
A149	Chabacano, durazno, melocotón	1
A150	Chicozapote y mamey	1
A151	Ciruela y jobo	1
A152	Guayaba	1
A153	Lima	1
A154	Limón	1
A155	Mandarina, nectarina, tangerina	1
A156	Toronja	1
A157	Mango	1
A158	Manzana y perón	1
A159	Melón	1
A160	Naranja	1
A161	Papaya	1
A162	Pera	1
A163	Piña	1
A164	Pitahaya y tuna	1
A165	Plátano macho y de castilla	1
A166	Plátano verde y tabasco	1
A167	Otros plátanos (chiapas, dominico, guineo, manzano, dorado, portalimón y roatan)	1
A168	Sandía	1
A169	Uva	1
A170	Otras frutas: garambullo, granada, higo, jícama, kiwi, etcétera	1
A171	Frutas en almíbar y conserva	3
A172	Frutas cristalizadas, enchiladas y secas	3
A173	Azúcar blanca y morena	3
A174	Miel de abeja	1
A175	Otras azúcares y mieles	3
A176	Café tostado en grano molido	3
A177	Café tostado soluble	3

ENIGH code	ENIGH description	WIOD sector
A178	Flor y hojas para té	1
A179	Té soluble (cualquier sabor)	3
A180	Chocolate en tableta	3
A181	Chocolate en polvo	3
A182	Otros chocolates	3
A183	Canela	1
A184	Clavo	1
A185	Yerbas de olor	1
A186	Concentrados de pollo y tomate	1
A187	Mayonesa	1
A188	Mole en pasta o en polvo	1
A189	Mostaza	1
A190	Pimienta	1
A191	Sal	1
A192	Salsas dulces y picantes	1
A193	Vinagre	1
A194	Otros aderezos, especies y salsas	1
A195	Cereal de arroz, avena, plátano, manzana, mixto para bebé	3
A196	Papillas para bebé	3
A197	Jugos de frutas y verduras de cualquier combinación para bebé	3
A198	Pizzas preparadas	22
A199	Carnitas	22
A200	Pollo rostizado	22
A201	Barbacoa y birria	22
A202	Otros alimentos preparados: atole, flautas, guisados, hot-dog, emparedados, sopas, tacos, tamales, tortas, sopes,	22
A203	Hongos frescos: champiñones, huitlacoche y setas	1
A204	Insectos: chapulines, chinicuiles, escamoles, gusanos de maguey, hormigas (chicatana), jumiles	1
A205	Flanes, gelatinas y pudines en polvo	3
A206	Cajetas, dulces de leche, jamoncillos y natillas	3
A207	Ates, crema de cacahuate, jaleas, mermelada	3
A208	Helados, nieves y paletas de hielo	3
A209	Otras golosinas	3
A210	Molienda de nixtamal	3
A211	Otros gastos relacionados con la preparación de alimentos	3
A212	Alimentos y/o bebidas en paquete	3
A213	Alimento para animales domésticos	3
A214	Alimento para animales para uso del hogar	3
A215	Agua natural embotellada	3
A216	Agua mineral, quina, desmineralizada con o sin sabor	3
A217	Agua preparada y jugos naturales	3

ENIGH code	ENIGH description	WIOD sector
A218	Jugos y néctares envasados	3
A219	Concentrados y polvos para preparar bebidas	3
A220	Refrescos de cola y de sabores	3
A221	Bebida energética	3
A222	Bebidas fermentadas de maíz, hielo, jarabe natural, lechuguilla, sangrita, tascalate, tepache y tuba	3
A223	Coñac y brandy	3
A224	Cerveza	3
A225	Anís (licor)	3
A226	Jerez	3
A227	Licor o cremas de frutas	3
A228	Aguamiel, pulque, tlachique	3
A229	Aguardiente, alcohol de caña, charanda, mezcal	3
A230	Ron añejo, blanco, con limón	3
A231	Rompope	3
A232	Sidra blanca y rosada	
A233	Tequila añejo, azul y blanco	3
A234	Vino de mesa blanco, rosado, tinto	3
A235	Vodka	3
A236	Whisky	3
A237	Bebida alcohólica preparada	3
A238	Otras bebidas alcohólicas: champaña	3
A239	Cigarros	3
A240	Puros	3
A241	Tabaco en hoja y picado	3
A242	Despensa de alimentos que otorgan organizaciones privadas o de gobierno	3
A243	Desayuno	22
A244	Comida	22
A245	Cena	22
A246	Entrecomidas	22
A247	Otros eventos fuera de casa	22
B001	Metro o tren ligero	23
B002	Autobús	23
B003	Trolebús o metrobús	23
B004	Colectivo, combi o microbús	23
B005	Taxi, radio-taxi (sitio)	23
B006	Autobús foráneo	23
B007	Otros transportes: lancha, panga o peaje	24
C001	Detergentes (polvo, líquido, pasta, gel)	9
C002	Jabón de barra	9
C003	Blanqueadores	9

ENIGH code	ENIGH description	WIOD sector
C004	Suavizantes de telas	9
C005	Limpiadores (en polvo o líquido)	9
C006	Servilletas y papel absorbente	7
C007	Platos y vasos desechables, papel aluminio y encerado	7
C008	Escobas, trapeadores, recogedor	16
C009	Fibras, estropajos, escobetas, pinzas para ropa, lazos	16
C010	Jergas y trapos de cocina	4
C011	Cerillos	16
C012	Pilas	14
C013	Focos	14
C014	Cera y limpia muebles	9
C015	Insecticidas líquido, en polvo, pastilla, raid eléctrico	9
C016	Desodorante ambiental y sanitario	9
C017	Recipientes de lámina (cubetas, tinas, etcétera)	12
C018	Recipientes de plástico (cubetas, tinas, mangueras, etcétera)	10
C019	Otros artículos	9
C020	Servicio doméstico	34
C021	Lavandería	34
C022	Tintorería	34
C023	Jardinería	34
C024	Otros servicios: fumigación, etcétera	34
D001	Jabón de tocador	9
D002	Lociones y perfumes	9
D003	Pasta dental y enjuague bucal	9
D004	Hilo y cepillo dental	16
D005	Champús, enjuagues, tratamiento para el cabello	9
D006	Tintes y líquidos para permanente	9
D007	Desodorante y talco	9
D008	Bronceadores y bloqueadores	9
D009	Crema para el cuerpo, para la cara y tratamiento facial	9
D010	Gel, spray, mousse para el cabello	9
D011	Crema para afeitar y rastrillos	9
D012	Cosméticos, polvo y maquillaje sombra, lápiz labial, delineador de ojos, etcétera	9
D013	Esmalte para uñas	9
D014	Papel sanitario, pañuelos desechables	7
D015	Toallas sanitarias	7
D016	Pañales desechables	7
D017	Artículos de tocador para bebé	7
D018	Cepillos y peines	16
D019	Artículos eléctricos: rasuradora, secadora, etcétera	13
D020	Reparación y/o mantenimiento de los artículos anteriores	21

ENIGH code	ENIGH description	WIOD sector
D021	Otros: donas y mariposas para el cabello, limas de uñas, pasadores, etcétera	16
D022	Corte de cabello y peinado	34
D023	Baños y masajes	34
D024	Permanentes y tintes	34
D025	Manicure	34
D026	Otros servicios: rasurar, depilar, etcétera	34
E001	Preescolar	32
E002	Primaria	32
E003	Secundaria	32
E004	Preparatoria o bachillerato	32
E005	Profesional	32
E006	Maestría y doctorado	32
E007	Educación Técnica	32
E008	Estancias infantiles (excepto preprimaria)	32
E009	Enseñanza adicional	32
E010	Educación especial para discapacitados	32
E011	Internados	32
E012	Cuidado de niños (persona particular)	33
E013	Transporte escolar	23
E014	Libros para la escuela	7
E015	Gastos recurrentes en educación, como: credenciales, seguro médico, seguro de vida, cuotas a padres de familia	32
E016	Pago de imprevistos como: derecho a examen, examen extraordinario, cursos de regularización, etcétera	32
E017	Equipo escolar: máquinas de escribir, calculadora, etcétera	32
E018	Gastos recurrentes en educación técnica: credenciales, seguro médico, seguro de vida, cuotas a padres de familia	32
E019	Pago de imprevistos para educación técnica, como: derecho a examen, cursos de regularización, etcétera	32
E020	Material para la educación adicional	32
E021	Reparación y/o mantenimiento de equipo escolar	32
E022	Enciclopedia y libros (excluya los de la escuela)	7
E023	Periódicos	7
E024	Revistas	7
E025	Audiocasetes, discos y discos compactos	7
E026	Otros	16
E027	Cines	34
E028	Teatros y conciertos	34
E029	Centros nocturnos (incluye alimentos, bebidas, tabaco, entrada, propinas, etcétera)	34
E030	Espectáculos deportivos	34

ENIGH code	ENIGH description	WIOD sector
E031	Lotería y juegos de azar	34
E032	Cuotas a centros sociales, asociaciones, clubes, etcétera	34
E033	Renta de casetes para videojuegos, discos compactos y videocasetes	30
E034	Otros gastos de recreación: museo, ferias, juegos mecánicos, balnearios, etcétera	34
F001	Instalación de la línea de teléfono particular	27
F002	Teléfonos celulares, pago inicial y equipo	27
F003	Compra de tarjeta para servicio de teléfono celular	27
F004	Teléfono público	27
F005	Estampillas para correo, paquetería, telégrafo	27
F006	Otros servicios: Internet público, fax público, etcétera	27
F007	Gasolina Magna	8
F008	Gasolina Premium	8
F009	Diesel y gas	8
F010	Aceites y lubricantes	8
F011	Reparación de llantas	19
F012	Pensión y estacionamiento	19
F013	Lavado y engrasado	19
F014	Otros servicios: encerado, inflado de llantas, etcétera	19
G001	Cuota por la vivienda recibida como prestación en el trabajo	28
G002	Cuota de la vivienda en otra situación	28
G003	Cuota o pago a otro hogar	28
G004	Alquiler de terrenos	30
G005	Recolección de basura	34
G006	Cuotas de vigilancia	31
G007	Cuotas de administración	31
G008	Otros servicios	31
G009	Gas licuado de petróleo	8
G010	Petróleo	8
G011	Diesel	8
G012	Carbón	8
G013	Leña	6
G014	Combustible para calentar	8
G015	Velas y veladoras	16
G016	Otros combustibles: cartón, papel, etcétera	7
G101	Renta o alquiler de la vivienda	29
G102	Estimación del alquiler de la vivienda que es prestada	29
G103	Estimación del alquiler de vivienda propia y se está pagando	29
G104	Estimación del alquiler de la vivienda que es propia	29
G105	Estimación del alquiler de vivienda intestada o en litigio	29
G106	Estimación del alquiler de la vivienda en otra situación	29
H001	Pantalones para niño de 0 a 4 años	4

ENIGH code	ENIGH description	WIOD sector
H002	Trajes, sacos, conjuntos, abrigos, gabardinas e impermeables para niño de 0 a 4 años	4
H003	Camisas para niño de 0 a 4 años	4
H004	Playeras para niño de 0 a 4 años	4
H005	Camisetas para niño de 0 a 4 años	4
H006	Suéteres, sudaderas y chambritas para niño de 0 a 4 años	4
H007	Pants para niño de 0 a 4 años	4
H008	Trusas y bóxer para niño de 0 a 4 años	4
H009	Calcetines, calcetas y tines para niño de 0 a 4 años	4
H010	Calzones de hule para niño de 0 a 4 años	4
H011	Pañales de tela para niño de 0 a 4 años	4
H012	Telas, confecciones y reparaciones para niño de 0 a 4 años	4
H013	Otras prendas de vestir: baberos, delantales, fajillas, batas, pijamas, etcétera para niño de 0 a 4 años	4
H014	Pantalones para niña de 0 a 4 años	4
H015	Trajes, sacos, conjuntos, abrigos, gabardinas e impermeables para niña de 0 a 4 años	4
H016	Vestidos y faldas para niña de 0 a 4 años	4
H017	Playeras para niña de 0 a 4 años	4
H018	Camisetas para niña de 0 a 4 años	4
H019	Suéteres, sudaderas y chambritas para niña de 0 a 4 años	4
H020	Blusas para niña de 0 a 4 años	4
H021	Pants para niña de 0 a 4 años	4
H022	Pantaletas para niña de 0 a 4 años	4
H023	Calcetas, tobilleras y tines para niña de 0 a 4 años	4
H024	Calzones de hule para niña de 0 a 4 años	4
H025	Pañales de tela para niña de 0 a 4 años	4
H026	Telas, confecciones y reparaciones para niña de 0 a 4 años	4
H027	Otras prendas de vestir: baberos, delantales, fajillas, batas, pijamas, etcétera (para niña de 0 a 4 años	4
H028	Pantalones para niño de 5 a 17 años	4
H029	Camisas para niño de 5 a 17 años	4
H030	Playeras para niño de 5 a 17 años	4
H031	Trajes, sacos, abrigos, gabardinas e impermeables para niño de 5 a 17 años	4
H032	Chamarras para niño de 5 a 17 años	4
H033	Suéteres y sudaderas para niño de 5 a 17 años	4
H034	Trusas y bóxer para niño de 5 a 17 años	4
H035	Camisetas para niño de 5 a 17 años	4
H036	Calcetines, calcetas y tines para niño de 5 a 17 años	4
H037	Pants para niño de 5 a 17 años	4
H038	Telas, confecciones y reparaciones para niño de 5 a 17 años	4

ENIGH code	ENIGH description	WIOD sector
H039	Otras prendas de vestir para hombre: corbatas, batas, pijamas, etcétera para niño de 5 a 17 años	4
H040	Pantalones para niña de 5 a 17 años	4
H041	Blusas para niña de 5 a 17 años	4
H042	Playeras para niña de 5 a 17 años	4
H043	Trajes, sacos, conjuntos, abrigos, gabardinas e impermeables para niña de 5 a 17 años	4
H044	Vestidos para niña de 5 a 17 años	4
H045	Faldas para niña de 5 a 17 años	4
H046	Suéteres y sudaderas para niña de 5 a 17 años	4
H047	Chamarras para niña de 5 a 17 años	4
H048	Calcetas, tobilleras, tines y mallas para niña de 5 a 17 años	4
H049	Pantaletas y fajas para niña de 5 a 17 años	4
H050	Brassieres para niña de 5 a 17 años	4
H051	Fondos y corpiños para niña de 5 a 17 años	4
H052	Medias, pantimedias y tobimedias para niña de 5 a 17 años	4
H053	Pants para niña de 5 a 17 años	4
H054	Telas, confecciones y reparaciones para niña de 5 a 17 años	4
H055	Otras prendas de vestir para mujer: rebozo, pijamas, camisones, batas, etcétera para niña de 5 a 17 años	4
H056	Pantalones para hombre de 18 o más años	4
H057	Camisas para hombre de 18 o más años	4
H058	Playeras para hombre de 18 o más años	4
H059	Trajes, sacos, conjuntos, abrigos, gabardinas e impermeables para hombre de 18 o más años	4
H060	Suéteres y sudaderas para hombre de 18 o más años	4
H061	Chamarras para hombre de 18 o más años	4
H062	Trusas y bóxer para hombre de 18 o más años	4
H063	Camisetas para hombre de 18 o más años	4
H064	Calcetines, calcetas y tines para hombre de 18 o más años	4
H065	Pants para hombre de 18 o más años	4
H066	Telas, confecciones y reparaciones para hombre de 18 o más años	4
H067	Otras prendas de vestir para hombre: corbatas, batas, pijamas, etcétera para hombre de 18 o más años	4
H068	Pantalones para mujer de 18 o más años	4
H069	Blusas para mujer de 18 o más años	4
H070	Playeras para mujer de 18 o más años	4
H071	Trajes, sacos, conjuntos, abrigos, gabardinas e impermeables para mujer de 18 o más años	4
H072	Vestidos para mujer de 18 o más años	4
H073	Faldas para mujer de 18 o más años	4
H074	Suéteres y sudaderas para mujer de 18 o más años	4

ENIGH code	ENIGH description	WIOD sector
H075	Chamarras para mujer de 18 o más años	4
H076	Calcetas, tobilleras, tines y mallas para mujer de 18 o más años	4
H077	Pantaletas y fajas para mujer de 18 o más años	4
H078	Brassieres para mujer de 18 o más años	4
H079	Fondos y corpiños para mujer de 18 o más años	4
H080	Medias, pantimedias y tobimedias para mujer de 18 o más años	4
H081	Pants para mujer de 18 o más años	4
H082	Telas, confecciones y reparaciones para mujer de 18 o más años	4
H083	Otras prendas de vestir para mujer: rebozos, pijamas, camisones, batas, etcétera para mujer de 18 o más años	4
H084	Zapatos para niño de 0 a 4 años	4
H085	Botas para niño de 0 a 4 años	4
H086	Tenis para niño de 0 a 4 años	4
H087	Huaraches para niño de 0 a 4 años	4
H088	Sandalias para baño o descanso para niño de 0 a 4 años	4
H089	Pantuflas para niño de 0 a 4 años	4
H090	Zapatos y sandalias para vestir para niña de 0 a 4 años	4
H091	Botas para niña de 0 a 4 años	4
H092	Tenis para niña de 0 a 4 años	4
H093	Huaraches para niña de 0 a 4 años	4
H094	Sandalias para baño o descanso para niña de 0 a 4 años	4
H095	Pantuflas para niña de 0 a 4 años	4
H096	Zapatos para niño de 5 a 17 años	4
H097	Botas para niño de 5 a 17 años	4
H098	Tenis para niño de 5 a 17 años	4
H099	Huaraches para niño de 5 a 17 años	4
H100	Sandalias para baño o descanso para niño de 5 a 17 años	4
H101	Pantuflas para niño de 5 a 17 años	4
H102	Zapatos y sandalias para vestir para niña de 5 a 17 años	4
H103	Botas para niña de 5 a 17 años	4
H104	Tenis para niña de 5 a 17 años	4
H105	Huaraches para niña de 5 a 17 años	4
H106	Sandalias para baño o descanso para niña de 5 a 17 años	4
H107	Pantuflas para niña de 5 a 17 años	4
H108	Zapatos para hombre de 18 o más años	4
H109	Botas para hombre de 18 o más años	4
H110	Tenis para hombre de 18 o más años	4
H111	Huaraches para hombre de 18 o más años	4
H112	Sandalias para baño o descanso para hombre de 18 o más años	4
H113	Pantuflas para hombre de 18 o más años	4
H114	Zapatos y sandalias para vestir para mujer de 18 o más años	4
H115	Botas para mujer de 18 o más años	4

ENIGH code	ENIGH description	WIOD sector
H116	Tenis para mujer de 18 o más años	4
H117	Huaraches para mujer de 18 o más años	4
H118	Sandalias para baño o descanso para mujer de 18 o más años	4
H119	Pantuflas para mujer de 18 o más años	4
H120	Servicio de limpieza y reparación de calzado	21
H121	Crema para calzado	9
H122	Otros: agujetas, cepillos, etcétera	16
H123	Bolsas	5
H124	Cinturones, carteras y monederos	5
H125	Diademas	16
H126	Encendedores, cigarreras y polveras	16
H127	Joyería de fantasía	16
H128	Portafolios	16
H129	Relojes de pulso	14
H130	Sombreros, gorros y cachuchas	4
H131	Otros accesorios: lentes oscuros, etcétera	14
H132	Artículos y accesorios para el cuidado del bebé	16
H133	Reparación y/o mantenimiento de los artículos anteriores	21
H134	Uniformes y prendas de vestir para actividades educativas, artísticas y deportivas	4
H135	Prendas de vestir para eventos especiales derivados de la educación	4
H136	Telas, confecciones y reparaciones	4
I001	Vajilla completa de cristal, barro, plástico, etcétera	16
I002	Piezas sueltas de vajilla de cristal, barro, plástico, etcétera	16
I003	Recipientes o cajas de plástico para la cocina	16
I004	Vasos, copas y jarras de cristal, plástico, cerámica, etcétera	16
I005	Cubiertos	16
I006	Plantas y flores artificiales, objetos de cerámica, orfebrería, porcelana, y otros artículos decorativos	16
I007	Accesorios de hule y plástico: jabonera, tapetes, espejos, etc.	16
I008	Reloj de pared o mesa	16
I009	Batería de cocina y piezas sueltas	16
I010	Olla express	16
I011	Otros utensilios: tijeras, abrelatas, pinzas para hielo, etc.	16
I012	Herramientas: martillo, pinzas, taladro, etcétera	16
I013	Reparación y/o mantenimiento de los artículos anteriores	16
I014	Colchones	4
I015	Colchonetas	4
I016	Cobertores y cobijas	4
I017	Sábanas	4
I018	Fundas	4
I019	Colchas, edredones	4

ENIGH code	ENIGH description	WIOD sector
I020	Manteles y servilletas	4
I021	Toallas	4
I022	Cortinas	4
I023	Telas, confecciones y reparaciones de artículos anteriores	4
I024	Hilos, hilazas y estambres	4
I025	Agujas, cierres, botones y broches	4
I026	Otros artículos: hamacas, almo-hadas, cojines, etc.	4
J001	Honorarios por servicios profesionales: cirugía, anestesia, etcétera, durante el parto	33
J002	Hospitalización, durante el parto	33
J003	Análisis clínicos y estudios médicos: Rayos X, ultrasonido, etcétera, durante el parto	33
J004	Medicamentos recetados y material de curación, durante el parto	9
J005	Servicios de partera, durante el parto	33
J006	Otros: servicio de ambulancia, etcétera, durante el parto	33
J007	Consultas médicas, durante el embarazo	33
J008	Consultas, placas, puentes dentales y otros, durante el embarazo	33
J009	Medicamentos recetados, durante el embarazo	9
J010	Vitaminas y complementos alimenticios, durante el embarazo	3
J011	Análisis clínicos y estudios médicos: rayos X, ultrasonidos, durante el embarazo	33
J012	Hospitalización durante el embarazo (no parto)	33
J013	Servicios de partera, durante el embarazo	33
J014	Hierbas medicinales, remedios caseros, etcétera, durante el embarazo	9
J015	Otros servicios: ambulancia, aplicación de inyecciones, vacunas, etcétera, durante el embarazo	33
J016	Consultas médico general	33
J017	Consultas médico especialista (pediatría y ginecología, etc.)	33
J018	Consultas dentales (placas dentales o prótesis dentales, etc.)	33
J019	Análisis clínicos y estudios médicos: rayos X	33
J020	Medicamentos recetados para: diarrea, infecciones y malestar estomacal	9
J021	Medicamentos recetados para: gripe	9
J022	Medicamentos recetados para: piel	9
J023	Medicamentos recetados para: alergias	9
J024	Medicamentos recetados para: tos	9
J025	Medicamentos recetados para: infecciones de la garganta	9
J026	Medicamentos recetados para: fiebre	9
J027	Medicamentos recetados para: inflamación	9
J028	Medicamentos recetados para: otras infecciones (antibióticos)	9
J029	Medicamentos recetados para: dolor de cabeza y migraña	9
J030	Medicamentos recetados para: otro tipo de dolores	9
J031	Medicamentos recetados para: presión arterial	9

ENIGH code	ENIGH description	WIOD sector
J032	Medicamentos recetados para: diabetes	9
J033	Medicamentos recetados para: vitaminas	9
J034	Medicamentos recetados para: anticonceptivos	9
J035	Otros medicamentos recetados	9
J036	Consultas médicas para el control de peso	33
J037	Medicamentos y productos para el control de peso	9
J038	Tratamiento para el control de peso	33
J039	Honorarios por servicios profesionales: cirujano, anestesista, etc.	33
J040	Hospitalización	33
J041	Análisis clínicos y estudios médicos (rayos X, electros, etc.)	33
J042	Medicamentos recetados y material de curación	9
J043	Otros: servicios de ambulancia, oxígeno, suero, sondas, bolsas de diálisis y de orina, cómodos, etc.	33
J044	Medicamentos sin receta para: diarrea, infecciones y malestar estomacal	9
J045	Medicamentos sin receta para: gripe	9
J046	Medicamentos sin receta para: piel	9
J047	Medicamentos sin receta para: alergias	9
J048	Medicamentos sin receta para: tos	9
J049	Medicamentos sin receta para: infecciones de la garganta	9
J050	Medicamentos sin receta para: fiebre	9
J051	Medicamentos sin receta para: inflamación	9
J052	Medicamentos sin receta para: otras infecciones (antibióticos)	9
J053	Medicamentos sin receta para: dolor de cabeza y migraña	9
J054	Medicamentos sin receta para: otro tipo de dolores	9
J055	Medicamentos sin receta para: vitaminas	9
J056	Medicamentos sin receta para: presión arterial	9
J057	Medicamentos sin receta para: diabetes	9
J058	Medicamentos sin receta para: anticonceptivos	9
J059	Otros medicamentos sin receta	9
J060	Algodón, gasas, vendas, etc.	33
J061	Alcohol, merthiolate, solución antiséptica, etcétera	33
J062	Consultas con el curandero, huesero, quiropráctico, etcétera	33
J063	Medicamento naturista, hierbas medicinales, remedios caseros	9
J064	Medicamento homeopático	9
J065	Anteojos y lentes de contacto	14
J066	Aparatos para sordera	14
J067	Aparatos ortopédicos y para terapia, silla de ruedas, andadera, muletas, etcétera	14
J068	Reparación y mantenimiento de aparatos ortopédicos	14
J069	Otros: pago de enfermeras y personal al cuidado de enfermos, terapias, etcétera	33
J070	Cuotas a hospitales o clínicas	33

ENIGH code	ENIGH description	WIOD sector
J071	Cuotas a compañías de seguros	28
J072	Cuotas de seguro popular	28
K001	Ventilador	13
K002	Aparatos telefónicos	13
K003	Identificador de llamadas, fax, etc.	13
K004	Aparatos de aire acondicionado para casa (incluye refrigeración o clima)	13
K005	Máquina de coser y accesorios	13
K006	Cocina integral	13
K007	Estufa de gas	13
K008	Estufa de otro combustible: electricidad, petróleo	13
K009	Refrigerador	13
K010	Licuadora	13
K011	Batidora	13
K012	Plancha	13
K013	Extractor de jugos	13
K014	Horno de microondas	13
K015	Lavadora	13
K016	Aspiradora	13
K017	Calentador de gas	13
K018	Calentador de otro combustible	13
K019	Lámparas eléctricas (incluye candiles)	13
K020	Lámparas de otro combustible	13
K021	Tanque de gas e instalación	13
K022	Lavadero, tinaco y bomba de agua	13
K023	Compra e instalación de paneles solares y planta de luz propia	13
K024	Otros aparatos: tostador, calefactor, horno eléctrico, etcétera	13
K025	Reparación, y/o mantenimiento de los artículos anteriores	13
K026	Juego de recámara	16
K027	Piezas sueltas de recámara: camas, tocadores, literas, etcétera	16
K028	Juego de comedor o antecomedor	16
K029	Piezas sueltas para comedor o antecomedor (mesas, sillas)	16
K030	Juego de sala	16
K031	Piezas sueltas para sala (mesa de centro) Muebles	16
K032	Muebles para cocina (gabinete, mesa, etcétera)	16
K033	Muebles para baño (taza, tina, tina de hidromasaje, etcétera)	16
K034	Muebles para jardín	16
K035	Alfombras y tapetes	16
K036	Otros muebles: libreros, escritorio, mesa para televisión, etcétera	16
K037	Reparación y/o mantenimiento de los artículos anteriores	16
K038	Materiales para reparación y mantenimiento	16
K039	Servicios de reparación y mantenimiento	18
K040	Materiales para ampliación y remodelación	18

ENIGH code	ENIGH description	WIOD sector
K041	Servicios para ampliación y remodelación	18
K042	Materiales para reparación y mantenimiento	18
K043	Servicios de reparación y mantenimiento	18
K044	Materiales para ampliación, construcción y remodelación	18
K045	Servicios para ampliación, construcción y remodelación	18
L001	Radio y radio despertador	13
L002	Estéreo y modular	13
L003	Grabadora	13
L004	Televisión blanco y negro (incluye portátil)	13
L005	Televisión color (incluye portátil), LCD y plasma	13
L006	Lector de DVD y Blu-Ray (incluye portátil)	13
L007	Computadora	13
L008	Accesorios para computadora (mouse, memorias usb, etc)	13
L009	Decodificador de T.V., control remoto, etcétera	13
L010	Accesorios: bocinas, audífonos, antena aérea, control remoto, etc.	13
L011	Videocasetes, cartuchos y discos para videojuegos	13
L012	Reproductor de discos compactos, MP3 y IPod (MP4)	13
L013	Reproductor de discos compactos, DVD para vehículos y autoestéreo	13
L014	Alquiler de televisión, videocaseteras, computadoras, etcétera	30
L015	Otros aparatos: Walkman, etc.	13
L016	Reparación y/o mantenimiento de los artículos anteriores	13
L017	Proyectores	14
L018	Cámaras fotográficas y de video	14
L019	Material fotográfico, películas	9
L020	Servicio fotográfico, revelado e impresión	30
L021	Otros artículos y servicios: tripié, alquiler de equipo, proyectores, etc.	14
L022	Reparación y mantenimiento de los artículos anteriores	21
L023	Juguetes, juegos de mesa	16
L024	Juegos electrónicos, videojuegos	16
L025	Instrumentos musicales	16
L026	Artículos de deporte y cacería (aparatos para ejercicio, etcétera)	16
L027	Artículos de jardinería: plantas, flores, macetas, tierra, abonos	1
L028	Reparación y/o mantenimiento de los artículos anteriores.	21
L029	Compra y cuidado de animales domésticos: patos, perros, etcétera	1
M001	Transporte foráneo	23
M002	Transporte ferroviario	23
M003	Transporte aéreo	25
M004	Servicio de carga y mudanza	23
M005	Cuotas de autopista	26
M006	Otros: lancha, barco, carreta, alquiler de vehículos, etcétera	24
M007	Automóvil y/o guayín	19
M008	Camioneta (pick up)	19

ENIGH code	ENIGH description	WIOD sector
M009	Motoneta, motocicleta	19
M010	Bicicleta	15
M011	Otros: remolque, lancha, triciclo, etcétera	15
M012	Llantas	19
M013	Acumulador	19
M014	Refacciones: bujías, bandas, filtros, etcétera	19
M015	Partes de vehículos: vidrios, salpicaderas, etcétera	19
M016	Accesorios: espejos, manijas, antenas, etcétera	19
M017	Servicios de afinación, alineación y balanceo	19
M018	Otros servicios: ajuste de motor, de frenos, hojalatería, pintura, etcétera	19
N001	Servicios profesionales de abogados, notarios, arquitectos, etcétera (no médicos)	31
N002	Funerales y cementerios	34
N003	Paquetes para fiesta (salón, comida, orquesta)	22
N004	Gastos turísticos: paquetes, hospedajes, alimentos, tours, etcétera	26
N005	Hospedaje o alojamiento sin fines turísticos (con o sin alimentos)	22
N006	Gastos en cargos comunales para festividades locales	34
N007	Contribuciones para obras del servicio público local	31
N008	Seguro de automóvil	28
N009	Seguros contra incendio, daños y riesgos para la vivienda, educación y seguro de vida (no capitalizable)	28
N010	Otros gastos diversos no comprendidos en las categorías anteriores	21
N011	Indemnizaciones pagadas a terceros	34
N012	Pérdidas y robos en dinero (excluya negocios)	34
N013	Ayuda a parientes y personas ajenas al hogar (en dinero)	34
N014	Contribuciones a instituciones benéficas en dinero, iglesias, cruz roja, incluye servicios eclesiásticos	34
N015	Servicios del sector público: expedición de pasaporte, actas, títulos, etcétera	31
N016	Trámites para vehículos: licencias, placas, verificación vehicular, etcétera	31
R001	Energía eléctrica	17
R002	Agua	17
R003	Gas natural	17
R004	Impuesto predial	31
R005	Largas distancias de línea particular	27
R006	Llamadas locales de línea particular	27
R007	Teléfonos celulares (plan mensual)	27
R008	Internet	27
R009	Televisión de paga	27
R010	Paquete de Internet y teléfono	27
R011	Paquete de Internet, teléfono y televisión de paga	27

ENIGH code	ENIGH description	WIOD sector
R012	Tenencia vehicular	19
R013	Alarmas para la casa	18
T901	Alimentos, bebidas y tabaco	3
T902	Transporte (pasajes)	23
T903	Artículos o servicios destinados a la limpieza y cuidados de la casa	9
T904	Artículos o servicios destinados a cuidados personales	9
T905	Artículos o servicios destinados a educación, cultura y recreación	34
T906	Artículos o servicios destinados a la comunicación y servicios para vehículos	27
T907	Artículos o servicios destinados a vivienda y servicios de conservación	21
T908	Último recibo pagado	21
T909	Prendas de vestir, calzado y accesorios	21
T910	Cristalería, blancos y utensilios domésticos	16
T911	Artículos o servicios destinados a cuidados de la salud	33
T912	Enseres domésticos y mantenimiento de la vivienda	21
T913	Artículos de esparcimiento	21
T914	Artículos o servicios destinados al transporte	23
T915	Gastos diversos	16
T916	Erogaciones financieras y de capital	28

Appendix C

Table C.1 ENIGH-WIOD reduced matching and carbon intensities

			CI (kg/MXN)	
Item	WIOD code	WIOD description	CO_2	CO_2e
Electricity	17	Electricity, Gas and Water Supply	0.290	0.297
Motor Fuels	8	Coke, Refined Petroleum	0.217	0.222
Gas	8	Electricity, Gas and Water Supply	0.140	0.140
Public Transport	23	Inland Transport	0.029	0.031
Food	1	Agriculture	0.032	0.173
	3	Food processing	0.016	0.044
Other	4	Textiles	0.017	0.024
	5	Leather, Footwear	0.013	0.019
	6	Wood and Wood Products	0.018	0.047
	7	Pulp, Paper	0.019	0.020
	8	Chemicals and Products	0.014	0.022
	9	Rubber and Plastics	0.013	0.015
	10	Other Non-Metallic Mineral	0.056	0.100
	11	Basic Metals and Fabricated Metal	0.021	0.028
	12	Machinery	0.005	0.006
	13	Electrical and Optical Equipment	0.008	0.009
	14	Transport Equipment	0.008	0.010
	15	Manufacturing; Recycling	0.022	0.027
	16	Construction	0.018	0.023
	17	Sale Motor Vehicles and Fuel	0.017	0.019
	18	Wholesale and Commission Trade	0.008	0.010
	19	Retail Trade	0.012	0.014
	20	Hotels and Restaurants	0.025	0.026
	21	Water Transport	0.147	0.152
	22	Air Transport	0.013	0.075
	23	Other Transport	0.018	0.019

Item	WIOD code	WIOD description	CI (kg/MXN)	
			CO_2	CO_2e
	24	Post and Telecommunications	0.008	0.009
	25	Financial Intermediation	0.004	0.005
	26	Real Estate Activities	0.004	0.004
	27	Renting of M&Eq and Other	0.009	0.010
	28	Public Admin and Defence	0.015	0.016
	29	Education	0.012	0.012
	30	Health and Social Work	0.011	0.013
	31	Other Services	0.013	0.101

Appendix D

Table D.1 SUSENAS-WIOD Matching 2014

SUSENAS code	SUSENAS description	WIOD sector
1	**CEREALS [R.2-R.9]**	
2	Rice	3
3	Glutinous rice	3
4	Fresh corn with husk	3
5	Dryshelled corn/corn rice	3
6	Rice meal	3
7	Corn meal	3
8	Wheat flour	3
9	Others	3
10	**TUBERS [R.11-R.19]**	
11	Cassava	1
12	Sweet potatoes	1
13	Sago flour	1
14	Taro	1
15	Potatoes	1
16	Dried cassava	1
17	Flour dried cassava	1
18	Cassava flour	1
19	Others	1
20	**FISH/SHRIMP/SQUID/SHELL [R.21-R.52]**	
21	Yellow tail/fusiliers	1
22	Eastern tuna/skipjack tuna	1
23	Mackerel	1
24	Trevallies	1
25	Indian mackerel	1
26	Anchovies	1
27	Milk fish	1
28	Snake head	1
29	Mozambique tilapia	1

SUSENAS code	SUSENAS description	WIOD sector
30	Common carp	1
31	Catfish	1
32	Barramundi	1
33	Baronang	1
34	Others	1
35	Shrimp	1
36	Common squid/cuttle fish	1
37	Mud crab/swim crab	1
38	Cockle/snail	1
39	Others	1
40	Indian mackerel	1
41	Mackerel	1
42	Eastern tuna/skipjack tuna	1
43	Anchovies	1
44	Trevallies	1
45	Snakeskin gourame	1
46	Milk fishes	1
47	Snake head	1
48	Canned fish	1
49	Others	1
50	Shrimps	1
51	Common squids	1
52	Others	1
53	**MEAT [R.54-R.70]**	
54	Beef	3
55	Buffalo meat	3
56	Lamb meat	3
57	Pork	3
58	Broiler meat	3
59	Local chicken meat	3
60	Other poultry meat	3
61	Other meat	3
62	Dried beef	3
63	Shredded fried meat	3
64	Canned meat	3
65	Others	3
66	Liver	3
67	Innards excluding liver	3
68	Trimming	3
69	Bone (untrimmed)	3
70	Others	3
71	**EGGS AND MILK [R.72-R.84]**	

SUSENAS code	SUSENAS description	WIOD sector
72	Broiler egg	3
73	Local chicken egg	3
74	Duck egg	3
75	Quail egg	3
76	Other egg	3
77	Salted egg	3
78	Fresh milk	3
79	Preserved milk	3
80	Sweet canned liquid milk	3
81	Canned powder milk	3
82	Baby powder milk	3
83	Cheese	3
84	Milk product	3
85	**VEGETABLES [R.86-R.114]**	
86	Spinach	3
87	Swamp cabbage	3
88	Cabbage	3
89	Chinese cabbage	3
90	Mustard greens	3
91	Beans	3
92	String bean	3
93	Tomato	3
94	Carrot	3
95	Cucumber	3
96	Cassava leaf	3
97	Aubergine	3
98	Bean sprout	3
99	Squash	3
100	Unripe corn	3
101	Soup/stir-fried vegetables	3
102	Sour vegetable soup	3
103	Young jackfruit	3
104	Unripe papaya	3
105	Mushroom	3
106	Petai beans	3
107	Stink beans	3
108	Onion	3
109	Garlic	3
110	Chillies	3
111	Green chili	3
112	Cayenne pepper	3
113	Canned vegetable	3

SUSENAS code	SUSENAS description	WIOD sector
114	Others	3
115	**LEGUMES [R.116-R.126]**	
116	Peanuts without shell	3
117	Peanuts with shell	3
118	Soybean	3
119	Mungbean	3
120	Red kidney bean	3
121	Other bean	3
122	Tofu, soybean curd	3
123	Fermented soybean cake	3
124	Fermented soybean paste	3
125	Fermented soya cake	3
126	Others	3
127	**FRUITS [R.128-R.150]**	
128	Orange	1
129	Mango	1
130	Apple	1
131	Avocado	1
132	Rambutan	1
133	Lanzon	1
134	Durian	1
135	Zalacca	1
136	Pineapple	1
137	"Ambon" banana	1
138	"Raja" banana	1
139	Other banana	1
140	Papaya	1
141	Rose-apple	1
142	Sapodilla	1
143	Carambola	1
144	Spanish plum	1
145	Watermelon	1
146	Melon	1
147	Jack fruit	1
148	Tomato	1
149	Canned fruit	1
150	Others	1
151	**OILS AND FATS [R.152-R.157]**	
152	Coconut oil	3
153	Corn oil	3
154	Other frying oil	3
155	Coconut	3

SUSENAS code	SUSENAS description	WIOD sector
156	Margarine	3
157	Others	3
158	**BEVERAGES [R.159-R.166]**	
159	Cane sugar	3
160	Brown sugar	3
161	T e a	3
162	Powdered/bean coffee	3
163	Instant cocoa	3
164	Powdered cocoa	3
165	Syrup	3
166	Others	3
167	**SPICES [R.168-R.180]**	
168	Salt	3
169	Candlenut	3
170	Coriander	3
171	Pepper	3
172	Tamarind	3
173	Nutmeg	3
174	Clove	3
175	Fish paste	3
176	Soya sauce	3
177	Monosodium glutamate	3
178	Chili sauce/tomato sauce	3
179	Spice	3
180	Other spice	3
181	**MISCELLANEOUS FOOD ITEM [R.182-R.190]**	
182	Instant noodle	3
183	Wheat noodle	3
184	Rice noodle	3
185	Macaroni	3
186	Crisps	3
187	Fried chips	3
188	Seaweed	3
189	Porridge in package	3
190	Others	3
191	**PREPARED FOOD AND BEVERAGES [R.192-R.222]**	
192	Ordinary bread	3
193	Other bread	3
194	Cookies	3
195	Boil or steam cake	3
196	Fried food	3

SUSENAS code	SUSENAS description	WIOD sector
197	Porridge of mung bean	3
198	Kind of salad with peanuts sauce	3
199	A plate of rice accompanied by a mixture of dishes	3
200	Fried rice	3
201	Rice	3
202	Rice steamed in a banana leaf or coconut leaf	3
203	Soup	3
204	Roasted meat on skewer/satay	3
205	Noodle (with meatball/boiled/fried)	3
206	Instant noodle	3
207	Snack for children	3
208	Fish (fried, roasted, etc)	3
209	Chicken/meat (fried, roasted, etc)	3
210	Other prepared food	3
211	Mineral water (bottle)	3
212	Mineral water (gallon)	3
213	Packed tea	3
214	Packed juice	3
215	CO2 drink	3
216	Health drink	3
217	Other drinks (coffee, milk, etc)	3
218	Ice cream	3
219	Other ice	3
220	B e e r	3
221	Wine	3
222	Other alcoholic beverage	3
223	**TOBACCO AND BETEL [R.224-R.229]**	
224	Clove filter cigarettes	3
225	Clove non filter cigarettes	3
226	Cigarettes	3
227	Tobacco	3
228	Betel/areca nut	3
229	Others	3
230	**HOUSING AND HOUSEHOLD FACILITY [R.231-R.260]**	
232	rent and house maintenance	29
233	rent and house maintenance	29
234	rent and house maintenance	29
235	rent and house maintenance	29
236	rent and house maintenance	29
238	electricity	17
240	water	17

SUSENAS code	SUSENAS description	WIOD sector
242	LPG	8
244	city gas	17
246	kerosene	8
248	generator fuel	8
250	generator: Lubricant oil	8
251	generator: maintenance and repair	21
253	charcoal/coal/briket	8
254	Firewood and other fuel	6
255	Others (flashlight, storage battery, matches, mosquito repellent, lamp, air freshener, Liquid floor cleaner, etc)	9
256	Post and Telecomunication:Phone bill (home)	27
257	Mobile phone bill	27
258	Phone card/public phone/phone shop	27
259	Post stuff (stamp, etc.)	27
260	Others (internet)	27
261	**GOODS AND SERVICES [R.262-R.302]**	
262	Bathing soap, toothpaste, and shampoo	27
263	Cosmetic articles	27
264	Treatment of skin, face, nails, hair	27
265	Laundry soap (bars, powders, creams, and liquid)	27
266	Clothes maintenance material (softener and fragrances, bleacing, lubricant, camphor, etc)	27
267	Newspapers, magazine, books, and stationeries (exluding for education) including magazine rent	27
268	Other stuffs (tissue, baby diaper, satai stick, etc.)	27
269	Health Care:Public Hospital	33
270	Private Hospital	33
271	Sub ordinary Public Health Center	33
272	Medical Doctor (including private medical doctor in public hospital)	33
273	Paramedical	33
274	Traditional treatment	33
275	Traditional birth attendant	33
276	Drug costs (only drugs purchased in pharmacies, drug stores, etc)	9
277	Self treatment/take medicine without recipe	9
278	Purchasing traditional medicine	9
279	Purchasing glasses, hand/leg artificial, & wheel chair	16
280	Health Preventive Cost Pregnancy examination cost	33
281	Children Under-fives immunization cost	33
282	Medical check-up	33
283	Contraception cost	33

SUSENAS code	SUSENAS description	WIOD sector
284	vitamin, medicine herbs, etc.	33
285	School fee and non/formal education cost	32
286	School fee	32
287	Other cost of school contribution	32
288	Text books	32
289	Stationery (pen, pencil, eraser, ruler, calculator, etc.)	32
290	Non-formal education cost	32
292	motor vehicle fuel: gasoline	19
294	motor vehicle fuel: diesel	19
296	motor vehicle fuel: lubricant	19
297	motor vehicle service and repair (brake fluid, battery acid, battery, brake, clutch, etc.)	19
298	Transport expenses (bus, train, plane, etc.)	23
299	Hotel, inn, cinema, theater, sports, set-top box, cable TV subscriptions (excluding transport and purchase of goods for recreation)	22
300	Domestic servant, security, and driver (salary or wages)	35
301	Financial service charge (ATM services, credit card services, transfer fees, etc.)	28
302	Other services (ID card, driver's license, birth certificate, copy, photo, etc.)	34
303	**CLOTHING, FOOTWEAR, AND HEADGEAR [R.304-R.311]**	
304	Ready-made clothes for men	4
305	Ready-made clothes for women	4
306	Ready-made clothes for children	4
307	Materials clothing for men, women, and children	4
308	Wages sewing, repairing clothes, sewing thread, and other goods for the purposes of tailoring	4
309	Footwear (shoes, sandals, socks, etc)	5
310	Headgear for men, women, and children (hat, cap, scarf, etc..)	4
311	Others (towel, belt, shoe polish, tie, laundry, etc.)	4
312	**DURABLE GOODS [R.313-R.329]**	
313	Furniture	6
314	Household furnishings (sewing machines, refrigerators, fans, washing machines, air conditioners, etc..)	14
315	Household equipments (mattresses, pillows, tablecloths, bed linen, ashtrays, pillowcases, blankets, mats, curtains, rugs, etc..)	16

SUSENAS code	SUSENAS description	WIOD sector
316	Home appliances (iron, broom, scissors, knives, machetes, hoes, saws, vacuum cleaner, coat hanger, soldering equipment, etc..)	16
317	Kitchen utensils (rack plate, stove, pots, pans, buckets, kitchen knives, pans, spoons, flasks, plates, glasses, mixers, rice cookers, blenders, microwaves, ovens, and other dishes made of glass / ceramic / melamine / plastic, etc..)	16
318	Decoration stuff (wall hangings, aquariums, decorative items made of ceramic, porcelain, onyx, marble, wood, etc..)	14
319	Furniture and utensils repairs	21
320	Hand phone and other accessories	14
321	Watch, clock, camera, glasses, and repairs	14
322	Umbrella, bag, and repairs	16
323	Jewelry and repairs	16
324	Toys and repair, imitation jewelry	16
325	Electronics (Television, radio, video, DVD, cassette, cassette radio, guitar, piano / organ, computer) and repair	14
326	Tools and sports equipment (chess, racket, ball, net, bet, sticks, including bathing suits, soccer shoes, wheels shoes , goggles) and repairs	16
327	Vehicles (cars, motorcycles, bicycles, etc..) and major repairs	19
328	Domestic animal and plant maintenance	1
329	Other durable goods (electrical installation / phone / tap, swing, stroller, etc..) and repairs	14
330	**TAXES AND INSURANCES [R.331-R.336]**	
331	Buildings and land taxes	28
332	Motor and non-motor vehicle taxes	28
333	Other contributions (dues RT / RW, trash, security, cemetery, parking, etc..)	28
334	Health insurance	28
335	Live insurance and general insurance (death insurance, accident, car, house, etc..)	28
336	Others (ticket, Income Tax, etc..)	28
337	**PARTIES AND CEREMONIES [R.338-R.343]**	
338	Wedding	34
339	Circumcision and birthday	34
340	Religious festival (chair rental, tent rental, etc..)	34
341	Pilgrimage cost	34

SUSENAS code	SUSENAS description	WIOD sector
342	Religious/traditional ceremony (called Ustad, Reverend, offerings, etc..)	34
343	Funeral expenses	34