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The impact of energy taxes on the affordability of domestic energy

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THE IMPACT OF ENERGY TAXES ON THE AFFORDABILITY OF DOMESTIC ENERGY

SUMMARY

Energy affordability can be defined as a household's ability to pay for necessary levels of energy use within normal spending patterns. This paper uses three indicators to measure energy affordability risk in 20 OECD countries at current taxes on electricity, natural gas and heating oil. Energy affordability risk differs widely between countries. The countries with the highest GDP per capita tend to have the lowest levels of energy affordability risk. The paper then analyses how indicators of energy affordability change in response to a hypothetical tax reform that introduces uniform taxes on natural gas, heating oil and electricity in all countries analysed, mostly increasing tax rates on these fuels. Results show that, if combined with an income-tested cash transfer using one third of the change in revenue resulting from the tax reform, the reform generally improves energy affordability. If combined with a lump-sum transfer instead, results show that energy affordability increases only according to the most selective of the three indicators.

L'IMPACT DE LA FISCALITÉ ÉNERGÉTIQUE SUR L'ACCESSIBILITÉ FINANCIÈRE DE LA CONSOMMATION INTÉRIEURE DE L'ÉNERGIE

BREF RÉSUMÉ

L'accessibilité financière de l'énergie désigne la capacité d'un ménage qui affiche des caractéristiques de dépenses normales à subvenir à ses besoins en énergie. Ce document utilise trois indicateurs pour mesurer le risque en matière d'accessibilité financière de l'énergie dans 20 pays de l'OCDE aux niveaux actuels des taxes sur l'électricité, le gaz naturel et le mazout. Les risques en matière d'accessibilité financière de l'énergie varient beaucoup d'un pays à l'autre. Les pays qui affichent les PIB par habitant les plus élevés sont aussi ceux où ces risques sont généralement les plus faibles. En outre, le document analyse l'évolution des indicateurs de l'accessibilité financière de l'énergie en réaction à une réforme fiscale hypothétique qui introduit des taxes uniformes sur le gaz naturel, le mazout et l'électricité dans tous les pays étudiés, principalement en relevant les taux des taxes sur ces combustibles. Les résultats montrent que si un tiers des changements des recettes générés par la réforme est reversé aux ménages au moyen de transferts sous condition de ressources, elle améliore leur accessibilité financière. En cas de transfert forfaitaire, les résultats révèlent que l'accessibilité financière s'améliore uniquement lorsqu'elle est mesurée avec le plus sélectif des trois indicateurs.

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THE IMPACT OF ENERGY TAXES ON THE AFFORDABILITY OF DOMESTIC ENERGY

EXECUTIVE SUMMARY

Motivation and scope

It is a tenet of environmental economics that including the costs of environmental damage to society in prices is a good way of reducing pollution at low cost. Taxes can accomplish such "internalisation" of the costs of pollution, and this often requires raising taxes from current levels. However, for regressive taxes, this has adverse equity effects unless the additional revenue is used to make the overall reform proportional or progressive. Taking a broader perspective, higher taxes may also increase energy affordability risks. Energy affordability can be defined as a household's ability to pay for necessary levels of energy use. Inadequate levels of electricity and heating use may compromise health and normal activity patterns. Without accompanying policies more households may face difficulty paying for necessary levels of energy use when energy taxes increase. Appropriate use of the additional revenue can reduce energy affordability risks, despite higher energy prices.

This paper examines three indicators of energy affordability and applies them to 20 OECD countries to measure energy affordability at current taxes on electricity, natural gas and heating oil. It then discusses the results of a simulation of a hypothetical energy tax reform which charges EUR 45 per tonne of carbon emissions and EUR 1 per GJ of energy, on heating fuels and electricity in all countries, generally increasing energy prices.

Because of data limitations the reform only changes tax rates for electricity, natural gas and heating oil. The latter two cover about 66% of household heating fuel used in the analysed countries, on average. Tax rates on solid fossil heating fuels (like peat or lignite briquettes) and district heating are unchanged. The reform replaces current taxes on domestic energy with a uniform tax across the analysed countries and redistributes a third of any additional tax revenues through cash-transfers – either lump sum or income-tested – to households. The main insights are as follows:

- There is no single best indicator of energy affordability on conceptual grounds, and different indicators give different results on the extent to which households in different countries face energy affordability risk. Indicators also differ in the extent to which they measure change in affordability risk in response to a price change.

- In practice, the "low-income, high-cost-share indicator" (LIHCS) is the most stringent and rich of the three indicators. This is by construction, as the LIHCS is a combination of the other two indicators, the "10% rule" (TPR) and the "relative poverty line" (RPL). Concretely, under the LIHCS, a household faces energy affordability risk if it both spends more than 10% of its income on domestic energy (TPR) and its income after energy expenditures is below 60% of the median household income (RPL).

Energy affordability risks differ widely across countries

Energy affordability risk differs widely between the 20 countries analysed, ranging from less than 3% of households in Switzerland to more than 20% in Hungary, according to the LIHCS indicator. The countries with the highest GDP per capita tend to also have the highest levels of energy affordability. High shares of households facing challenges to afford energy are mostly observed in Central European countries.

Countries with higher GDP per capita tend to have lower energy affordability risk. In contrast, higher energy taxes or prices do not correlate with higher energy affordability risk. One potential explanation for the latter observation is that higher energy prices over time lead to higher energy efficiency, so mitigating the effects of higher costs per unit of energy. Another possibility is that countries that might expect that high energy prices would particularly harm poor households, try to keep them low. In addition, higher energy prices may over time also trigger increases in wages, which would reduce energy affordability risks.

The impacts of an energy tax reform on energy affordability

Simulation results show that a reform that increases taxes on heating fuels and electricity can reduce energy affordability risk if parts of the additional revenues are transferred back to households using an income-tested cash transfer. In many countries, transferring a third of the additional revenues to poor households is sufficient to reduce energy affordability risk. According to the TPR and the LIHCS, energy affordability risk decreases noticeably, on average by 4.8% and 5.8% across countries. Real incomes also increase for the lowest two deciles when governments provide income-tested transfers.

With a uniform lump-sum transfer to all households, energy affordability only improves according to the LIHCS indicator, while it declines noticeably as measured by the TPR. This is because the LIHCS – in contrast to the TPR – excludes households that do not fall below the poverty line after expenditures on energy, even if they spend more than 10% of their income on energy. These households have relatively higher incomes, so 10% or more translates into higher absolute spending on energy. This spending, which is high enough that a uniform transfer is insufficient to counteract the increase in energy prices, translates into increased energy affordability risks under the TPR, but not under the LIHCS, as the households that do not fall below the poverty line are excluded.

While richer households are affected more by an increase in taxes on domestic energy in absolute terms, such taxes are still likely to be regressive if no additional policy measures are implemented. Lump-sum transfers can mitigate regressive impacts, while income-tested transfers can result in a progressive impact of the tax reform overall.

L'IMPACT DE LA FISCALITÉ ÉNERGÉTIQUE SUR L'ACCESSIBILITÉ FINANCIÈRE DE LA CONSOMMATION INTÉRIEURE DE L'ÉNERGIE

RÉSUMÉ

Motivation et portée

En vertu d'un principe fondamental de l'économie environnementale, intégrer les coûts des dommages environnementaux pour la société dans les prix est un bon moyen de réduire la pollution à moindre frais. Les taxes peuvent accomplir cette « internalisation » des coûts de la pollution, ce qui suppose souvent de relever leur niveau. Néanmoins, dans le cas d'impôts régressifs, l'alourdissement de la fiscalité a des effets négatifs sur l'équité, sauf si les recettes supplémentaires servent à rendre la réforme globale plus proportionnelle ou progressive. Dans une optique plus large, relever les taxes peut aussi accroître les risques en matière d'accessibilité financière de l'énergie, à savoir la capacité d'un ménage à subvenir à ses besoins en énergie. L'incapacité à satisfaire ses besoins en électricité et en chauffage peut avoir des conséquences néfastes sur la santé et sur l'activité. Sans politiques d'accompagnement, les ménages risquent d'être plus nombreux à rencontrer des difficultés à financer leur consommation d'énergie lorsque les taxes augmentent. Le bon usage des recettes supplémentaires peut réduire les risques d'accessibilité financière, malgré la hausse des prix de l'énergie.

Ce document examine trois indicateurs et les applique à 20 pays de l'OCDE afin de mesurer l'accessibilité financière de l'énergie aux niveaux actuels des taxes sur l'électricité et sur les combustibles de chauffage. Il décrit ensuite les résultats d'une simulation d'une réforme hypothétique de la fiscalité énergétique qui applique une taxe de 45 EUR par tonne d'émissions de carbone et de 1 EUR par gigajoule d'énergie sur les combustibles de chauffage et l'électricité dans tous les pays, augmentant des prix de l'énergie en général.

En raison des limites des données, la réforme modifie uniquement les taux des taxes sur l'électricité, le gaz naturel et le mazout. Le gaz naturel et le mazout couvrent en moyenne environ 66 % de la consommation de combustibles de chauffage des ménages dans les pays analysés. Les taux des taxes sur les combustibles fossiles solides (comme la tourbe ou les briquettes de lignite) et le chauffage urbain restent inchangés. La réforme remplace les taxes actuelles sur l'énergie intérieure par une taxe uniforme dans tous les pays analysés, et redistribue un tiers des recettes fiscales supplémentaires via des transferts – soit forfaitaires, soit sous condition de ressources – aux ménages. Les principaux enseignements sont les suivants :

- Aucun indicateur à lui seul ne rend parfaitement compte, pour des raisons conceptuelles, de l'accessibilité financière de l'énergie, et différents indicateurs aboutissent à différents résultats quant au risque d'accessibilité financière rencontré par les ménages dans différents pays. En outre, les indicateurs ne rendent pas également compte de l'effet d'un changement de prix sur le risque d'accessibilité financière.

- Dans la pratique, l'indicateur de la part des ménages à bas revenu et à proportion de coût élevé (*low-income, high-cost-share*, LIHCS en anglais) est le plus complet et le plus rigoureux des trois indicateurs. Il est construit à partir des deux autres indicateurs, la « règle des 10 % » (*10% rule*, TPR en anglais) et le seuil de pauvreté relative (« *relative poverty line*, RPL en anglais). Concrètement, selon cet indicateur, un ménage est confronté à un risque d'accessibilité financière

de l'énergie s'il consacre plus de 10 % de son revenu à l'énergie (TPR) et si son revenu après dépenses d'énergie est inférieur au 60 % du revenu médian des ménages (RPL).

Les risques d'accessibilité financière varient considérablement d'un pays à l'autre

Les risques en termes d'accessibilité financière de l'énergie sont très variables entre les 20 pays analysés, puisqu'ils vont de moins de 3 % des ménages en Suisse à plus de 20 % en Hongrie, selon l'indicateur LIHCS. Les pays qui affichent les niveaux les plus élevés de PIB par habitant sont aussi ceux où les niveaux d'accessibilité financière de l'énergie sont les plus élevés. C'est dans les pays d'Europe centrale que l'on observe le plus de ménages ayant des difficultés à subvenir à leurs besoins en énergie.

Le risque est généralement plus faible dans les pays enregistrant un PIB par habitant élevé. En revanche, un niveau élevé des taxes sur l'énergie ou des prix de l'énergie n'est pas corrélé à un risque élevé d'accessibilité financière. Cela peut s'expliquer par le fait qu'un renchérissement des prix de l'énergie conduit progressivement à une amélioration de l'efficience énergétique, ce qui atténue les effets d'une augmentation du coût par unité d'énergie. Il se peut également que les pays qui s'attendent à ce que des prix élevés de l'énergie soient particulièrement préjudiciables pour les ménages pauvres s'efforcent de maintenir ces prix à un bas niveau. En outre, une augmentation des prix de l'énergie peut aussi entraîner à terme une augmentation des salaires, qui viendrait réduire les risques d'accessibilité financière.

L'impact d'une réforme de la fiscalité de l'énergie sur l'accessibilité financière

Les résultats de la simulation montrent qu'une réforme visant à relever les taxes sur les combustibles de chauffage et sur l'électricité peut réduire le risque d'accessibilité financière de l'énergie si une partie des recettes supplémentaires est reversé aux ménages au moyen de transferts sous condition de ressources. Dans de nombreux pays, le transfert d'un tiers des recettes supplémentaires aux ménages pauvres suffit à atténuer le risque d'accessibilité financière. Mesuré par les indicateurs TPR et LIHCS, ce risque décroît sensiblement, de 4.8 % à 5.8 % en moyenne entre pays. Les revenus réels progressent également pour les deux déciles inférieurs lorsque les États effectuent des transferts sous condition de ressources.

En cas de transfert forfaitaire uniforme à l'ensemble des ménages, l'accessibilité financière s'améliore uniquement lorsqu'elle est mesurée au moyen de l'indicateur LIHCS, tandis qu'elle se dégrade nettement avec l'indicateur TPR. En effet, l'indicateur LIHCS, contrairement au TPR, ne tient pas compte des ménages qui, une fois leurs dépenses d'énergie effectuées, ne se situent pas au-dessous du seuil de pauvreté, même s'ils consacrent plus de 10 % de leur revenu à l'énergie. Ces ménages ont des revenus relativement élevés, de sorte qu'une fraction du revenu de 10 % ou plus consacrée à l'énergie se traduit par une hausse des dépenses d'énergie absolues. Ces dépenses, dont le niveau est suffisamment important pour qu'un transfert uniforme ne permette pas de compenser la hausse des prix de l'énergie, se traduisent par une augmentation des risques d'accessibilité financière selon le TPR, mais pas selon le LIHCS, car les ménages qui se situent au-dessus du seuil de pauvreté sont exclus.

Bien que les ménages plus aisés soient davantage affectés par une hausse des taxes sur l'énergie intérieure en termes absolus, il est probable que ces taxes conservent leur effet régressif en l'absence de mesures supplémentaires. Des transferts forfaitaires peuvent atténuer l'impact régressif, tandis que la réforme fiscale dans son ensemble peut avoir un effet progressif si les pouvoirs publics optent pour des transferts sous condition de ressources.

1. Introduction

Taxes on the use of energy are often too low to reflect the costs of pollution and climate change resulting from energy use (see, for example, OECD, 2016). Higher taxes on energy use, however, translate into higher household energy prices and also put upward pressure on the prices of other goods and services, depending on how energy-intensive they are. Such price increases may not be particularly burdensome for higher income households, but for lower income households or households with elevated energy needs, they may pose problems of affordability, both in general and in relation to energy. Higher energy prices may force some households to decrease heating and electricity use to inadequate levels, resulting in low comfort or compromising health and normal activity patterns. Alternatively, some households may choose to cut spending on other items, also resulting in reduced well-being. Flanking policies, e.g. cash transfers, can help mitigate such adverse affordability impacts. This paper uses household-level spending data to investigate the affordability of energy; more specifically of heating fuels and electricity, at current prices and in a counterfactual energy tax scenario, in 20 OECD countries.

While the concept of energy affordability has intuitive appeal, it is not easy to define, and difficult to capture in a simple indicator. The paper presents some commonly used indicators of affordability, based on data on expenditures or on income, or both. The discussion in Section 2 reveals that not all expenditure- and income-based indicators meet basic consistency requirements concerning their responsiveness to price and income changes. Section 3 calculates three indicators of energy affordability that do pass the consistency check, at current energy prices. The "low-income, high-cost-share" indicator combines the requirements of the two other indicators. It uses information on expenditure shares and relative household income, both of which are relevant to affordability, and appears to be both simple and informative.

At current prices, energy affordability differs strongly across countries. Differences in average per capita GDP explain some of the variation, but energy tax or price differences do not. The latter plausibly is the case because household expenditure is price elastic in the long run, so that expenditure impacts of higher prices are not, or only partly, picked up by the indicators. Alternatively, decision-makers might keep energy prices low where affordability challenges are more likely to occur. In the former case, high taxes still negatively impact welfare or well-being, but this would not be captured in the energy affordability indicators.

In order to obtain insights into the risk that higher energy prices reduce energy affordability, Section 4 of the paper discusses simulations of a reform that harmonises, across countries, taxes on fuels used for heating and for electricity generation, at EUR 1 per GJ and EUR 45 per tonne of CO_2. The tax component on the energy content of fuels reflects that countries tax fuels to raise revenue and EUR 1 per GJ is about the average effective tax rate on heating fuels and electricity in OECD countries (OECD, 2013). The tax component on the carbon content of fuels brings energy users closer to paying for damage that their carbon emissions cause to society. In addition, it is assumed that a third of any additional revenue is recycled to households, either as an income-tested cash transfer or as a uniform lump sum transfer. In countries where the reform implies lower taxes, the reduction in revenues translates into reduced transfers to households.

Results indicate that, with income-tested cash transfers, energy affordability often increases despite the higher prices. Moreover, under the "low-income, high-cost-share" indicator, the same holds if uniform lump-sum transfers are used instead of income-tested compensation. The general insight is that using part of the revenues from higher energy taxes can be sufficient to alleviate the increased affordability risks resulting from the price increases. The simulations consider direct effects of the reforms under two assumptions on household energy demand. First, no change in demand is considered, approximating the immediate effects of the reform. Second, it is assumed that energy demand declines in response to higher energy prices over time. General equilibrium effects are not considered. Given the size of the price changes in some of the countries analysed, reverberations throughout the economy could materialise (e.g. via higher

wages, general upward price pressure, and potential effects of the use of revenues net of compensation given). The modelling tools do not allow consideration of such effects, however.

Energy affordability is an important consideration in evaluations of the impacts on households of higher energy prices, but it is not the only one. Other effects of interest include incidence across income or expenditure deciles, where regressive impacts often are taken to be undesirable.[1] Changes in household welfare also matter. Section 4.3 shows that an energy tax reform can be proportional or even progressive when higher taxes are combined with income-tested transfers. Lump-sum transfers reduce, but do not undo, the regressive impact of higher energy prices. Deploying one third of the change in revenues from the energy tax reform for income-tested transfers increases households' real incomes – a rough approximation of welfare impacts – in the lowest two deciles. In higher deciles, the transfers mitigate part of the negative real income effect resulting from higher energy prices. With income-tested transfers, the middle deciles face the largest real income decline, whereas with lump-sum transfers, the real income decline is larger in lower income deciles.

The paper is structured as follows. Section 2 introduces different indicators of energy affordability, discusses some of their properties, and selects three indicators that will be used in the subsequent analysis. Section 3 shows how energy affordability varies strongly across countries and explores potential explanations for this variation. Section 4 discusses the impacts of the hypothetical energy tax reform on energy affordability. It also sheds light on the distributional impacts of the reform and on potential welfare impacts. Section 5 summarises the findings.

2. Measuring energy affordability

There is no universally accepted definition of energy affordability, but the concept is frequently used, and low affordability is often taken to refer to a combination high energy spending and low income. Energy affordability is different from energy poverty, which refers to situations where households lack access to modern energy services[2] (especially in lower-income countries) and to low energy affordability combined with low energy efficiency (Pye and Dobbins, 2015). One definition of energy affordability is that it is a household's ability to pay for necessary levels of energy consumption within normal spending patterns (Milne, 2004). If necessary levels of consumption and normal spending patterns were defined precisely, energy would either be affordable or not. However, such precise definitions are elusive, and indicators of energy affordability therefore are necessarily somewhat arbitrary and can be seen as indicating low or reduced affordability, rather than necessarily pointing to unaffordability. A pragmatic way forward is to accept a degree of arbitrariness and to interpret the indicators as capturing the risk that a household is not able to afford energy in the sense of the definition. Aggregating indicators over the population of households then allows statements about the degree of energy affordability and how it changes as policies or market conditions change.

This section reviews indicators of energy affordability for households, focussing on how they respond to price and income changes, and selects three indicators for the subsequent analysis. In line with most of the literature, the discussion is limited to domestic energy use, i.e. heating and electricity, excluding household transport energy use. The analysis of affordability of transport services and transport energy use

1. There is a discussion of whether to measure distributional effects best on an income or expenditure basis. Measurement on income basis allows for direct comparison with other taxes and transfers, which are typically calculated on an income basis, while expenditure is generally considered to be a better measure of life-time income and well-being.

2. www.iea.org/topics/energypoverty/

poses specific challenges, e.g. relating to the connection between services and energy use, and to defining minimal service requirements, which are outside of the scope of this paper.

Table 1 lists five indicators of energy affordability. The "Ten Percent Rule" (TPR) and the "Double Median Rule" (2M) focus on expenditure shares, relating energy affordability challenges to expenditure shares exceeding a given threshold. The "Minimum Income Standard" (MIS) and the "Relative Poverty Line" (RPL) define energy affordability in terms of disposable income after expenditure on energy. A third class of indicators, including the "Low-Income, High-Cost" (LIHC) indicator and the "Low-Income, High-Cost-Share" (LIHCS) indicator, combine notions of expenditure and disposable income.

Table 1. Response of energy affordability indicators to price and income changes

Acronym	Description	Criteria – Energy affordability problems if:	Position invariant burdening	Impoverishment
TPR	10% rule	Energy expenditure share 10% or more **AND** in bottom three income deciles	Yes	Yes
2M	Double median rule	Energy expenditure share exceeds twice that of the median household	No	No
MIS	Minimum income standard	Disposable income after energy expenditure below absolute poverty line	Yes	Yes
RPL	Relative poverty line	Disposable income after energy expenditure below relative poverty line	Yes	Yes
LIHC	Low-income, high-cost	Energy expenditure exceeds median **AND** RPL	No	No
LIHCS	Low-income, high-cost-share	TPR **AND** RPL	Yes	Yes

The TPR says that households spending more than 10% of disposable income on heating fuels and electricity face challenges in affording energy (Boardman, 1991). To avoid counting high-income households that deliberately spend a higher percentage of disposable income on domestic energy rather than facing affordability constraints, e.g. by not switching off appliances or turning off the heating or cooling when not needed, only households in the lower three income deciles are considered in relation to this indicator. Apart from this, no information other than expenditure shares is used. Other indicators compare a household's expenditure share to the median household's share. For example, the 2M indicator assesses whether domestic energy expenditure share is at least twice the median expenditure share of all households. A third commonly used indicator is the LIHC standard, which asks if a household's energy expenditure is above the median and whether it falls below the poverty line after expenditure on domestic energy. The "income poverty" indicators (MIS and RPL) ask whether a household falls below the poverty line after accounting for all expenditure on domestic energy. Lastly, the LIHCS combines the requirements of the TPR and the RPL.

The United Kingdom used the TPR to measure energy affordability in its entire territory, often also referred to as fuel poverty, until 2012. Since 2013, England applies the LIHC criterion, while Northern Ireland, Scotland and Wales remain with the TPR (DECC, 2016). The change in England was the result of a review of energy affordability (Hills, 2012) which claimed that the LIHC standard better identifies households that face enduring affordability problems, for example due to living in a poorly insulated home. A relative indicator of energy expenditures (expenditure above the median) responds less strongly to energy price changes than an absolute expenditure threshold (10%) and puts therefore more focus on households that permanently face problems to afford energy. An absolute expenditure threshold, in comparison, puts more weight on how energy price changes affect energy affordability. In addition, as will be seen below, while an absolute expenditure threshold responds consistently to price changes, a relative

threshold can result in a measured improvement of energy affordability in response to an increase in energy prices or a decline in income.

In France, the Observatoire national de la précarité énergétique (ONPE, 2016 and 2014) uses three indicators for measuring energy affordability. The set consists of the TPR, the LIHC and a survey-based indicator that asks households whether they feel cold in their homes. The authors of the reports argue that while the LIHC standard may capture in particular those households facing enduring energy affordability challenges, it does not always appropriately reflect the impacts of rising or falling energy costs (see below), an issue not faced by the TPR. The survey-based indicator is seen as a complement to the two expenditure-based indicators. It indicates whether households can afford to heat to a comfortable level in their own judgment.

Whichever indicator is chosen, it should capture the essence of how energy affordability changes when energy prices or incomes change. In this context, Heindl and Schüssler (2015) find that, while all indicators discussed above help to assess energy affordability of domestic energy use, not all of them respond appropriately to changes in energy prices or income. More specifically, some fail two criteria of plausibility, namely *position invariant burdening* and *impoverishment*:[3]

- *Position invariant burdening* requires that, if the relative position of all households in the distribution of income remains the same when all incomes are reduced by a positive amount, then the indicator should not indicate improved affordability. The intuition is that an overall decline in income should not lead to a measured improvement in affordability.
- The *impoverishment* criterion requires that there is an amount of energy expenditure, or a ratio of energy expenditure to income, at which any household would face a challenge to afford adequate domestic energy use. This is tantamount to saying that energy affordability problems can exist and sensible indicators should pick them up at some point.

Indicators that rely on multiples of the median (e.g. 2M) or other percentiles of expenditure or income do not satisfy *position invariant burdening* (Heindl and Schüssler, 2015). By these indicators, a rise in the energy expenditure of all households (i.e. a real income reduction) that does not affect the ordering and relative position of households in terms of energy expenditure can lead to an increase in measured energy affordability. Suppose, for example, that the median share of expenditure spent on domestic energy is 5% and that the household spending that median share earns EUR 2000 per month, so its expenditure on energy is EUR 100. Suppose further that energy expenditure increases by EUR 100 for all households. The median share household will now spend EUR 200 on domestic energy and the median expenditure share increases to 10%. The 2M threshold now increases to 20% (twice the median share), while energy expenditures have only increased by EUR 100 to 10%. Since the threshold increases by twice the increase in energy expenditure, fewer households exceed it, even though energy use has become more expensive for all households, so affordability cannot improve.

Indicators that rely on a relative expenditure threshold like the median, e.g. the LIHC, may not comply with the *impoverishment* criterion (Heindl and Schüssler, 2015). A household which spends nearly its entire income on energy, but whose overall spending on energy is below the median, will not be classified as energy-poor according to this indicator, even if the expenditure pattern suggests

3. Measures of energy affordability relate two different variables with each other, i.e. expenditure on energy and disposable income or expenditure on energy and overall expenditure. While there is a large literature on the properties of poverty measures that rely only on one variable, e.g. income or expenditure (cf. Kakwani, 1980; Sen, 1976), Heindl and Schüssler (2015) explore the properties of affordability or poverty measures that relate these two variables.

impoverishment. The LIHC thus fails to recognise that households with fairly low spending on energy but very low income can face problems to afford energy.

The failure of the 2M and LIHC indicators to comply with the *position invariant burdening* criterion or the *impoverishment* criterion makes these indicators unreliable for comparisons across time and place. For example, comparing two countries that are similar in nearly all aspects but differ in their energy prices, the 2M and LIHC indicators could suggest, erroneously, that the country with higher energy prices would also have higher energy affordability. The LIHC also does not take into account the distribution of income, especially in lower income deciles. While in one country, expenditure on domestic energy below the median can indeed be compatible with lower-decile households still being able to afford energy, it may not in a second country, where incomes for households at the low end of the distribution are very low and energy affordability becomes truly problematic.

Indicators that compare disposable income after expenditure on energy services to the poverty line, like the MIS, meet the *position invariant burdening* and *impoverishment* criteria but they rely heavily on how the poverty line is defined. Poverty lines may be defined in absolute terms, for example comparing incomes of households to the cost of a certain basket of goods. If households that earn less than what the basket of goods costs, they are considered to be poor. In this case, it is not straightforward to know whether the indicator of energy affordability decreased because people spent more on energy or because the absolute poverty line has increased due to non-energy price increases. Also, there might be differences in how absolute poverty lines are calculated across countries, making such indicators less convenient for cross-country comparisons. Defining the poverty line in relative terms, e.g. at 60 % of median income as commonly applied, overcomes this problem. Accordingly, the RPL states that a household faces problems to afford energy if its income after energy expenditures falls below the relative poverty line, set in each country at 60% of its median income for this paper.

The LIHCS is interpretable as the intersection of the TPR and the RPL, as it requires both that households spend more than 10% of their disposable income on domestic energy and that they fall below the poverty line after expenditure on domestic energy. It is the most selective indicator in the sense that households must not only spend a high share of their income on energy, but also earn a low income to be considered as facing problems to afford energy. As will be seen in Section 4, this double requirement can have significant effects on how the number of households that face challenges in affording energy changes in response to an energy tax reform. This is particularly the case compared to the other indicators.

The analysis in Sections 3 and 4 of the paper will use the TPR, the RPL and the LIHCS indicators. These all meet the two plausibility criteria and use a relative poverty line, so can be compared across countries.

3. Indicators of energy affordability in 20 OECD countries

This section shows calculations of the three indicators of energy affordability identified in the previous section, namely the 10% rule (TPR), the relative poverty line (RPL) and the low-income and high-cost-share criterion (LIHCS) for 20 OECD countries[4]. The analysis uses expenditure micro-level data from household budget surveys (HBSs) to calculate domestic energy expenditures and to model energy taxes. The HBSs are sample surveys of households carried out periodically by National Statistical Offices.

4. The micro-level data required to calculate the three indicators of energy affordability was obtained from Austria, Belgium, Chile, the Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Poland, the Slovak Republic, Slovenia, Spain, Switzerland, Turkey and the United Kingdom. See Annex B for further detail.

They provide detailed information on household consumption expenditure on goods and services, possession of durable goods and on housing. They include demographic and socio-economic characteristics of the surveyed households, including disposable income. Regarding domestic energy use, the data covers household expenditures for heating fuels and electricity. The data are comparable across countries because they use identical or at least strongly similar survey formats. Details on the method and data can be found in Annex B.

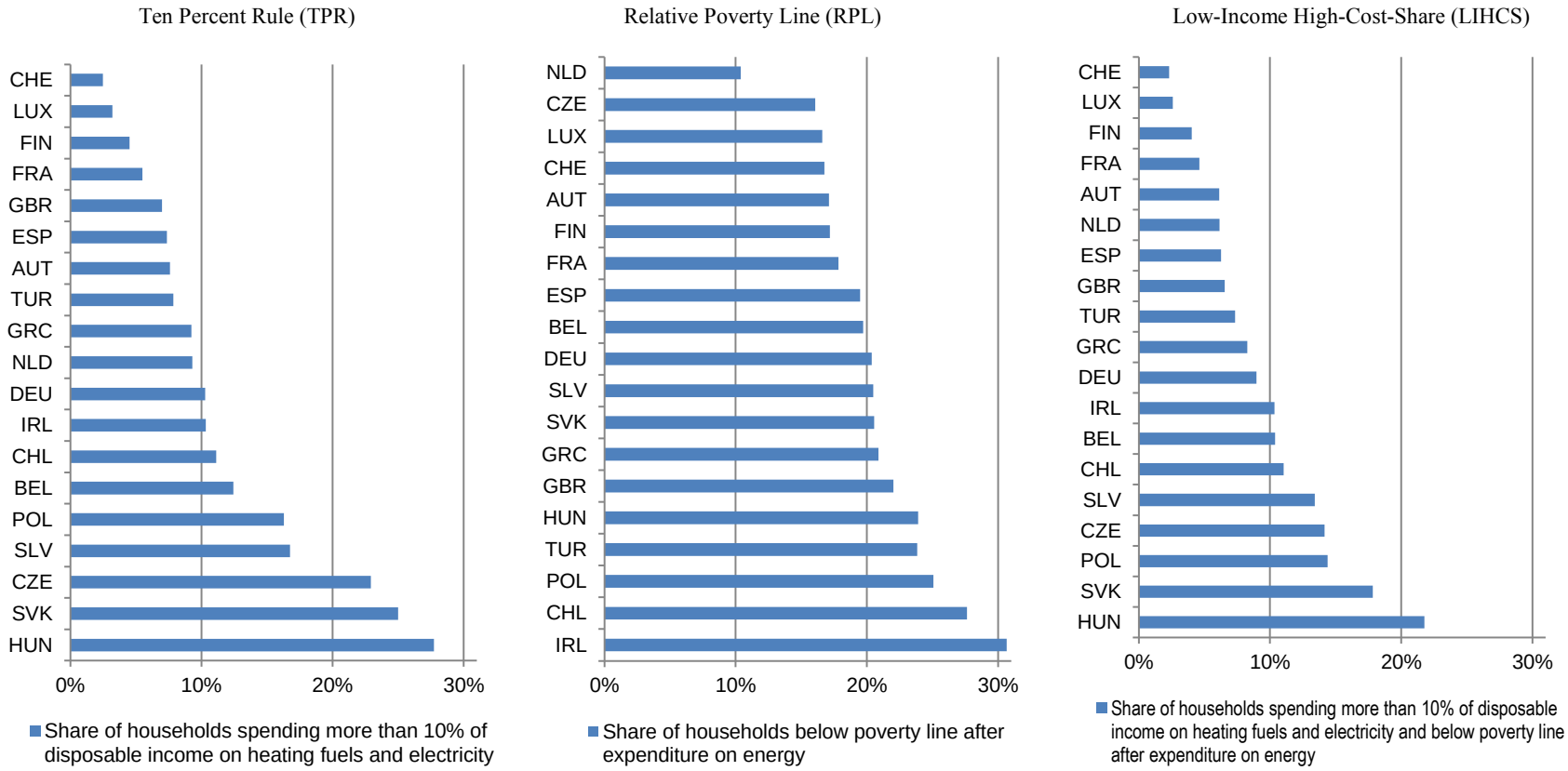
3.1 Comparing TPR, RPL and LIHCS

The following three indicators, all fulfilling the *position invariant burdening* and *impoverishment* criteria, will be used for comparing energy affordability across OECD countries: the TPR, the LIHCS and the RPL. According to the TPR, households spending more than 10% of disposable income on domestic energy face energy affordability risk. It can also more simply be regarded as an indicator that shows how many people have relatively high domestic energy costs. The LIHCS defines a household to face energy affordability risk when it spends more than 10% of disposable income on domestic energy and also falls below the relative poverty line, set at 60% of median income, after expenditure on energy. The adjustment to the relative poverty line ensures that the LIHCS indicator responds consistently to price and income changes, in contrast to LIHC. The RPL indicates that households face challenges to afford energy if they fall below the relative poverty line of 60% of the median income after expenditures on domestic energy.

Figure 1 shows that energy affordability varies strongly across countries, by all three indicators.[5] There are also strong differences between indicators in terms of the rate of households facing energy affordability risk, and to a lesser degree in terms of country rankings. Looking at the TPR, only 2.5% of households in Switzerland spend more 10% of their disposable income on domestic energy while 27.7% of all households do so in Hungary. In the middle, the Netherlands have just fewer than 10% of households facing energy affordability risk. The LIHCS produces a country ranking similar to the TPR, but finds somewhat lower rates of affordability risk in general. In some cases, however, the decline is large: in Hungary, the share decreases from 27.7% to 21.8 %; in the Slovak Republic, from 25% to 17.8%; and in the Czech Republic from 22.9% to 14.1%. The LIHCS indicates that only 2.3% of all households face challenges in affording domestic energy in Switzerland, while 21.8% do so in Hungary. Greece is the median country here, with around 8% of households facing energy affordability risk. According to the RPL, more households risk not being able to afford energy: 10.4% of all households fall below the relative poverty line after energy expenditure in the Netherlands, 30.7% do so in Ireland, and the median country (Germany) has more than 20% of households subject to energy affordability risk. Country rankings differ too. For example, the Czech Republic has the 3rd highest share of households facing energy affordability risk according to TPR, while it has the second lowest according to RPL. In the other direction, the United Kingdom has the fifth lowest share according to the ten percent indicator, but the sixth highest according to the relative poverty line indicator.

5. The affordability measures are calculated based on data from household budget surveys, which most, but not all, countries analysed conducted in 2010. See Annex B for additional detail.

Figure 1. Energy affordability varies considerably across selected OECD countries

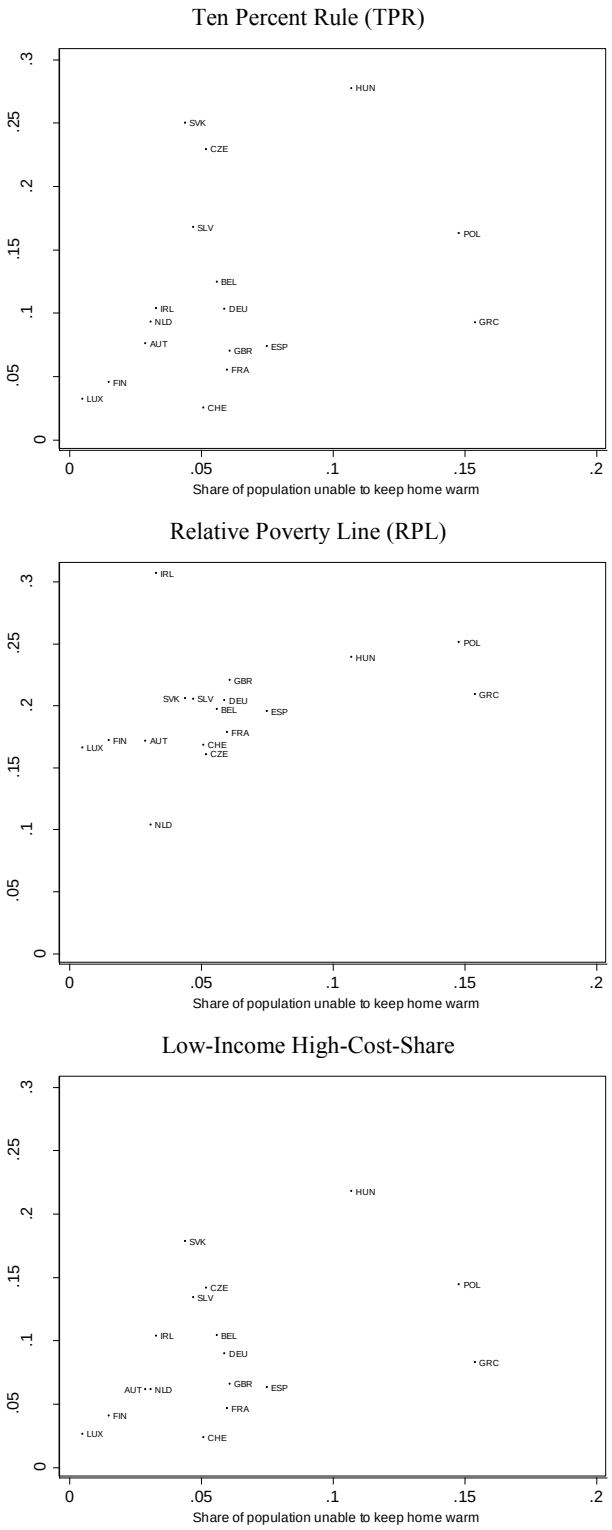


Comparing RPL to the TPR and LIHCS, it becomes obvious that high expenditures on energy matter less for the relative poverty line indicator. Under RPL, it suffices that a household falls below the poverty line after expenditures on domestic energy, but the level of expenditure as such does not matter. The relative poverty indicator measures only to a limited extent how far expenditures on energy lead to poverty (and in that sense may be more indicative of poverty after energy expenditures than of energy affordability). The TPR and the LIHCS, in contrast, only categorise households with relatively high energy expenditures relative to their income as facing challenges in affording energy.

Figure 2 relates the energy affordability indicators to subjective statements of individuals about their ability to heat their home adequately. The data stems from the European Union Statistics on Income and Living Conditions (EU-SILC) survey (Eurostat, 2015a). There is a positive correlation between the subjective statements and the three indicators of energy affordability,[6] suggesting that the three indicators reflect spending constraints rather than preference-driven choices to keep energy expenditures low.

6. The correlation coefficients between the TPI, RPL, LIHCS and the share of the population unable to keep its house warm are 0.32, 0.4 and 0.41, respectively. The correlation between the LIHCS and the share of the population unable to keep its house warm is significant at the 10% level.

Figure 2. Countries with many households feeling unable to keep home warm tend to have lower energy affordability



Notes: All values for the year of the household budget survey, see Annex B.
Sources: Share of population unable to keep home warm from Eurostat (2015a).

3.2 Exploring determinants of energy affordability

Table 2 investigates how the three energy affordability indicators relate to potential explanatory factors. The idea here is not to undertake an in-depth investigation of what explains energy affordability problems (the analysis establishes no causality), but to explore how indicators of income, inequality, energy taxes and prices, climate and housing quality relate to energy affordability. The table shows that, overall, only few meaningful relationships emerge.

Higher GDP per capita clearly relates to a lower share of households facing energy affordability challenges, by all three indicators. Looking more closely at the TPR, a simple linear regression indicates that a 1% increase in GDP per capita relates to about a 1% decrease in the share of households spending more than 10% of disposable income on domestic energy. This result is robust to including the additional explanatory variables shown in Table 2 in a multiple regression framework. Furthermore, GDP is the only variable in a multiple regression using all variables shown in Table 2 (including either energy prices or taxes) that is consistently statistically significant across many specifications of the regressions. While higher income reduces the share of households with high domestic energy expenditure, no consistent relationship between income inequality – as measured by the Gini index – and high energy expenditure is indicated by Table 2.

Table 2. GDP per capita is an important determinant of energy affordability

	Ten Percent Rule		**Relative Poverty Line**		**Low-Income High-Cost-Share**	
	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P-Value
GDP per capita	**-0.55**	0.02	**-0.41**	0.08	**-0.61**	0.01
Gini index	-0.24	0.31	**0.54**	0.02	-0.11	0.64
Avg. tax on heating	-0.28	0.25	**-0.59**	0.01	-0.35	0.14
Avg. tax on electricity	-0.11	0.67	**-0.55**	0.02	-0.17	0.48
Avg. price of heating	-0.02	0.94	-0.20	0.41	-0.05	0.85
Avg. price of electricity	0.00	1.00	-0.09	0.72	0.00	1.00
Heating days	0.06	0.80	-0.16	0.53	0.02	0.95
Poor dwelling	0.20	0.43	0.11	0.67	0.27	0.30

Notes: All values for the year of the household budget survey, see Annex B, for 19 OECD countries except where noted otherwise; Sources: GDP per capita in purchasing power adjusted constant USD from OECD (2014c); Gini coefficient of disposable income from OECD (2015); Average tax on heating oil and natural gas and average tax on electricity, own calculation based on European Commission (2013) and IEA (2014); Average price of heating oil and natural gas and average price of electricity, own calculation based on European Commission (2014) Eurostat (2014a, 2014b, 2013a, 2013b) and IEA (2014); Heating days from Eurostat for 18 countries (2015b); Poor dwelling quality from Eurostat (2015c) for 17 countries.

Table 2 also shows no strong association between the share of households facing challenges to afford energy, and taxes on heating fuels and on natural gas, except for the relative poverty line indicator, where higher taxes correlate with lower affordability problems. This last result, however, is driven largely by the Netherlands, which has the highest tax rate on heating and electricity in the selected OECD countries as well as the lowest share of households falling below the poverty line after energy expenditures. The correlation coefficients drop significantly when the Netherlands is not included, and for electricity taxes, the coefficient is also no longer statistically significant.

While the finding that energy affordability is not related to the level of energy taxes, or if even negatively as for the relative poverty line, may surprise, at least three explanations are possible. First, countries that expect that taxes on energy use would particularly harm poor households may opt for low taxes on energy. Second, high energy taxes might not increase the share of households with high energy spending. This would be the case if higher energy taxes reduce energy use by an equal factor or greater. Third, higher energy prices may trigger wage increases over time and the higher wages reduce energy

affordability risk in turn. Wage increases may however also increase inflation, putting downward pressure on real wages, and diminishing the reduction in energy affordability risk.

A significant negative correlation between taxes and energy prices would support the first explanation that countries that expect that taxes on energy use would particularly harm poor households may opt for low taxes on energy. Countries with high pre-tax prices on energy, e.g. due to unfavourable geographical location or path-dependencies leading to high generation-costs for electricity, may opt for low energy taxes with an aim of keeping energy affordable. While there is a negative correlation of 0.2 between electricity prices and taxes, this correlation is not statistically significant. For heating fuel prices and taxes there is a positive, statistically insignificant correlation of 0.27. These statistically insignificant correlations, that are low in absolute values, indicate that high energy taxes are not related to high energy prices when compared across countries.

Energy prices and taxes also appear to be unrelated to living in a cool climate. While the correlation coefficients between average prices on heating oil and gas (-0.07), as well as average prices on electricity (-0.23) have a negative sign, they are small in size and not statistically significant. Average taxes on heating fuels and electricity correlate positively with heating days, but the coefficients are also small, 0.29 and 0.09 respectively, and statistically insignificant.

Overall, Table 2 does not reveal any clear relationship between the indicators of energy affordability and average prices for heating fuels and electricity, nor between a cool climate and low energy prices or taxes. These findings indirectly support the second explanation given above, namely that households adjust to higher energy prices over time by reducing their energy use. The extensive literature on the price elasticities of fuels indeed shows that energy demand falls as prices rise, although not always by enough to keep expenditures constant (Rothman et al., 1994; OECD, 2000; Espey and Espey, 2004; Alberini, 2011). Also the third explanation, that wages may increase in response to higher energy prices, may explain the lack of any relationship between indicators of energy affordability and prices for domestic energy. Aside from noting that some countries index wages for inflation, which provides a link between energy prices and wages, this seems to be an area of research yet to explore.

Meta-studies suggest mean estimates of price elasticities close to but often smaller than one (in absolute terms), although there is huge variation in estimates depending on the method and the data employed (cf. e.g. OECD, 2000; Espey and Espey, 2004). Studies that control for many, potentially endogenous, factors or rely mainly on variation across short time horizons typically find lower estimates (below 1) than studies that rely on cross-sectional studies and that control only for factors that are not endogenous in the long-term. A cross-section finding can be interpreted as the results of a long-run equilibrium in that it includes all adjustment processes that have taken place. Controlling for some endogenous factors, like energy efficiency of appliances, implies estimating a short-term elasticity.

Taking all arguments together, it is plausible that higher energy prices reduce energy demand by almost enough to keep expenditures constant over the long run. Should higher energy prices also increase wages, the reductions in energy demand needed to keep energy expenditure in terms of income constant are lower accordingly. The results in Table 2, which shows the cross section of high domestic energy expenditures and energy prices, are consistent with such a long-term relationship between energy expenditures and energy prices, assuming that there are no other factors that lead to systematically low energy prices in countries with high energy expenditures.

Table 2 does not show any relationship between a high share of disposable income spent on heating fuels and electricity and the number of heating days in the country. Heating days are calculated by Eurostat (2012) by considering how frequently outdoor temperature is below 18 degrees Celsius. While one might have expected that more heating days relate to a higher share of people with high energy expenditures, the results rather suggest that households may adapt to a colder climate with better insulation or other

adaptation mechanisms. Governments may also apply stricter insulation standards in countries with a cool climate.

The finding that there is no direct relationship between poor dwelling quality and the share of households with high domestic energy expenditure may also surprise. However, the Euro-SILC questionnaire asks individuals whether their home has a leaking roof, damp walls, floors or foundation, or rot in window frames or floors to assess building quality. This indicator may not directly relate to energy efficiency and insulation and thereby not give very much information about energy expenditures in relation to income. Dwelling quality is more directly related to energy poverty than to energy affordability (Pye and Dobbins, 2015)

Returning to Figure 1, a very high share of households with high domestic energy expenditure is observed for many Central and Eastern European countries. Tirado Herrero and Ürge-Vorsatz (2012) note that, in many of these countries, a significant amount of the population lives in prefabricated concrete-slab construction buildings ("slab-buildings"), which were built in response to high demand for living space. Many of these buildings do not allow for individual heat metering. Instead, the heat supplied to the building is billed to individual apartments in proportion to their size. Some, especially older, buildings also do not have the possibility to regulate the amount of heat supplied, sometimes leading households to open a window to decrease the indoor temperature. Tirado Herrero and Ürge-Vorsatz argue that the combination of (forced) high temperatures and billing by size leads to high heating expenditures, resulting in a particular type of energy affordability challenge.

In this context, the Czech Republic, implementing the EU directive 2002/91/EC on the energy performance of buildings, has required that heating be billed according to energy use since January 2015.[7] While the cost of the necessary equipment is low, anecdotal evidence indicates a drop in energy use for heating of 10% to 20%. A case study prior to the reform (Vlček and Charvátová, 2012) finds that the average indoor-temperature in a particular tower slab-building in Prague dropped by 0.43 degrees Celsius after joule-meters had been installed in each apartment. Also the share of apartments with an average January indoor temperature above 23 degrees Celsius dropped from 37% to 29%. This suggests that giving households the possibility to respond to higher energy prices is essential for achieving energy savings.

Summing up the cursory evidence, GDP per capita is an important determinant of the affordability of domestic energy. Countries with higher taxes on heating fuels and electricity do not have higher shares of households subject to energy affordability risk, which may be because households adjust to higher energy taxes and prices in the long term.

These tentative findings do not imply that energy taxes and prices can be increased without affecting households at all. One reason is that short- and medium-term impacts matter, and adjustment costs can be large. Short-term impacts are discussed in the next section. A second potential reason is that energy affordability indicators do not give comprehensive measurements of the impact of energy prices on household welfare or well-being (see Section 4.3). If price increases are less than fully compensated by reductions in demand, so that total expenditures rise, then expenditure cuts need to be made elsewhere unless households are compensated for the increase.

4. The impacts of a hypothetical energy tax reform on energy affordability

Section 3 described the current levels of energy affordability challenges according to three indicators. This section investigates how energy affordability would change in response to a hypothetical energy tax

7. This requires that joule-meters or heat indicators, i.e. appliances that measure energy use for heating, to be installed in each apartment.

reform that is combined with a transfer to households of one third of the change in tax revenue resulting from the reform.

4.1 Nature of the tax reform and impact on energy prices

Affordability indicators are useful for country comparisons. The previous section has shown that country rankings differ between indicators (but less so when relying on indicators that emphasise the energy expenditure share) in ways that are related to income but not so much to price or tax levels. A second, perhaps more important, application of the indicators is their ability to gauge how energy affordability responds to policy changes. For example, climate and environment concerns call in many countries for higher energy taxes on most fuels, but how does this affect energy affordability? To shed light on this question, this section discusses the changes in energy affordability that would result from a reform of taxes on heating fuels and electricity. One third of the change in revenues raised after the reform, compared to the current situation, is recycled to households, either as a uniform or as an income-tested transfer. Box 1 summarises the reform, and the following paragraphs provide additional detail.

Box 1. The hypothetical energy tax reform

The hypothetical tax reform *replaces* the existing taxes on heating fuels (natural gas and heating oil) and on electricity with the same taxes on electricity and on heating fuel in all of the 20 countries analysed. This results in uniform taxes across all countries, but not in uniform prices as pre-tax prices differ. No other changes to taxes or prices are made.

The uniform tax on domestic energy contains an energy component of EUR 1 per GJ and a carbon component of EUR 45 per tonne of CO_2. Summing up the energy and the carbon component and expressing total tax rates in volumetric units this amounts to about EUR 0.15 per litre of heating oil, and EUR 0.13 per m^3 of natural gas. For electricity, the energy component is translated into a tax on electricity use, with the rate chosen to yield the same revenue as an input tax on fossil fuels of EUR 1 per GJ. Assuming a 40% average efficiency of electricity generation, this usage tax amounts to EUR 0.009 per kWh.

The uniform tax is higher than existing taxes in most countries, but is lower in some countries. Electricity taxes and taxes on natural gas increase in 19 out of 20 countries. Taxes on heating oil increase in thirteen of the countries analysed and decrease in seven. The differences between the fuels reflect the observation that taxes on oil products often are higher than taxes on other fuels (see e.g. OECD, 2013). Note also that the tax increase often is larger for gas than for heating oil. This reflects the higher initial taxes for heating oil. After the reform, the taxes are uniform in terms of the treatment of carbon and energy content of the fuels. Where energy taxes increase, tax revenue increases, and where they decline, revenue declines. This is so in the counterfactual scenario where demand is kept constant, but also in the scenario where demand is elastic, because the price elasticity is smaller than one (in absolute terms). In the hypothetical tax reform, the change in revenues partly translates into a change in transfers made to households. Two types of cash transfers are considered, namely an income-tested transfer and a lump-sum transfer. For both rules, one third of the change in tax revenue is recycled via changes in transfers. The remaining two thirds are abstracted from in the analysis.

The income-tested cash transfer includes a basic amount and a sum for every adult and child in each household, which declines with income. The transfer is also higher where the household reference person is retired, to reflect higher domestic energy needs, and it includes an in-work amount. Specifically, households that earn up to half of the average income receive the full cash transfer; above this level, the cash transfer is reduced by EUR 0.20 for each additional Euro earned until the transfer is exhausted.

The tax rates used in the simulations should not be seen as reflecting a policy preference. Setting tax rates uniformly across countries allows for a comparison of energy affordability in a scenario in which only factors other than tax differ. This means that any differences in energy affordability have to be explained by factors that are not taxes. The rates are arbitrary but comparable to existing rates and carbon values taken in cost-benefit analysis: EUR 1 per GJ is about the effective tax rate on heating fuels and on electricity inputs in OECD countries (OECD, 2013); EUR 45 per tonne of CO_2 approximates the carbon values used by the European Commission and the United States in cost-benefit analyses of public policies in 2020 (Smith and Braathen, 2015). In the scenario energy taxes thus bring energy users closer to pay for the damage that their carbon emissions cause to society while considering at the same time that countries also tax energy use and services in order to raise revenues.

The reform replaces the current taxes on heating fuel and on electricity in 20 OECD countries with a tax that is uniform across countries and that consists of an energy content component and a carbon content

component. Uniformity across countries is chosen to facilitate comparison in a scenario where only factors other than tax differ. The rates are essentially arbitrary but comparable to existing rates and costs of carbon emissions used in cost-benefit analysis. The energy component is set at EUR 1 per GJ and could reflect that countries tax fuels to raise revenues. EUR 1 per GJ is about the effective tax rate on heating fuels and on electricity inputs in OECD countries (OECD, 2013).[8] The carbon component, set at EUR 45 per tonne of CO2, would bring energy users closer to paying for the damage that their carbon emissions cause to society. EUR 45 per tonne of CO_2 approximates the social costs of carbon as used by the European Commission and the United States in cost-benefit analyses of public policies in 2020 (Smith and Braathen, 2015).[9]

Table 3 shows the price changes that result from the reform for electricity, natural gas and heating oil in the countries covered. Across countries, electricity prices increase by 11.4% on average, natural gas prices by 15.8% and heating oil prices by 5.5%. Inter-country variation, however, is large, reflecting the considerable prevailing heterogeneity in energy prices (OECD, 2013). Electricity prices fall strongly in the Netherlands, hardly change in some countries, and increase by more than 20% in several cases.[10] The tax reform implies stronger price increases for natural gas than for electricity in many cases. In the case of heating oil, there are price reductions in seven countries, reflecting relatively high prevailing taxes on oil products.

8. In the case of electricity, the energy component is modelled as a tax on electricity use, with the rate chosen to yield the same revenue as an input tax on fossil fuels of EUR 1 per GJ. Assuming a 40% average efficiency of electricity generation and no behavioural changes, this usage tax is EUR 0.009 per kWh. While the efficiency of electricity generation can differ across countries, applying the same usage tax for all countries eases modelling and comparison of the tax reform across countries.

9. Alternative reform scenarios might consider increases in energy taxes proportional to existing taxes. This would ignore, however, that some fuels are already taxed close to their social costs in some countries, while other fuels are hardly taxed or not taxed at all, see also Box 1.

10. For the Netherlands, the price decrease for electricity and natural gas is due to high current marginal tax rates on these goods. The lump-sum transfers that households receive with their electricity bill and that affect average, but not marginal, electricity and natural gas prices, are not taken into account in this calculation. Average prices decrease less than marginal prices assuming the lump-sum transfer is not changed. In the simulations, however, the lump sum transfer drops as a consequence of reduced tax revenue.

Table 3. Price changes resulting from the hypothetical energy tax reform

	Electricity	Natural Gas	Heating Oil
AUT	0.1%	10.5%	8.5%
BEL	7.6%	17.1%	21.1%
CHE	7.2%	11.8%	11.7%
CHL	12.5%	15.5%	21.7%
CZE	21.7%	17.9%	17.5%
DEU	0.5%	8.4%	10.9%
ESP	9.1%	21.5%	9.3%
FIN	0.5%	0.0%	-1.1%
FRA	7.0%	12.6%	10.6%
GBR	16.5%	28.5%	5.0%
GRC	22.8%	0.0%	14.5%
HUN	12.8%	24.7%	-18.1%
IRL	32.1%	23.9%	24.6%
ITA	9.7%	11.1%	-21.5%
LUX	12.0%	23.2%	24.1%
NLD	-15.8%	-4.6%	-9.0%
POL	24.3%	28.2%	13.9%
SLV	20.2%	10.8%	-0.9%
SVK	10.0%	14.0%	-10.1%
TUR	16.7%	39.9%	-22.4%
Average	11.4%	15.8%	5.5%

With respect to heating fuels, the tax reform applies only to heating oil and natural gas, covering about 66% of household heating fuel use in the analysed countries, but a considerably lower share in some countries (see Annex C). No tax reform on solid fossil heating fuels (like peat or lignite briquettes) and district heating is modelled. Solid fossil heating fuels are used only to a minor extent in many of the analysed countries. District heating is often not taxed. In the case where district heating is a by-product of electricity generation, the implicit assumption is that heat generation is 100% efficient and that fuel inputs are taxed via rates on electricity. For heat-only plants, no tax reform is modelled.

In all simulations, a third of the change in revenues resulting from the change in tax rates is transferred back to households. Two redistribution mechanisms are considered, namely an income-tested cash transfer benefitting in particular poor households, and a uniform lump-sum transfer. In countries where the tax reform implies a tax increase, the resulting increase in revenues translates into higher transfers. In countries where taxes decline, the transfers decline by the same token.

The income-tested cash transfer includes a basic amount and a sum for every adult and child in each household, which declines with income. The transfer is also higher where the household reference person is retired, to reflect higher domestic energy needs, as these persons spend more of their time at home than others. In order to counteract discouragement from working, the cash transfer includes an in-work amount. Specifically, households that earn up to half of the average income receive the full cash transfer; above this level, the cash transfer is reduced by EUR 0.20 for each additional Euro earned until the transfer is exhausted. Equation 1 summarises the calculation of the income-tested cash transfer:

$$\begin{aligned} cash\ transfer = {} & basic\ amount + \ adult\ amount * number\ of\ adults + child\ amount \\ & * number\ of\ children + retired\ amount * \mathbf{1}[\boldsymbol{if}\ household\ head\ retired] \\ & + inwork\ amount * \mathbf{1}\ [\boldsymbol{if}\ household\ head\ working] - 0.2 * income \\ & * \mathbf{1}[\boldsymbol{if}\ income > 0.5 * average\ income] \qquad (1) \end{aligned}$$

The simulations are carried out under two assumptions on household demand. First, no change in demand in response to the price changes is considered. This can be thought of as capturing the immediate impact of the reform, before any behavioural adjustment takes place. Second, it is assumed that households will adjust their energy consumption in response to the price change. A price elasticity of 0.8 is assumed for heating fuels and 0.6 for electricity. These values roughly reflect available evidence (Rothman et al., 1994; OECD, 2000; Espey and Espey, 2004; Alberini, 2011).[11]

4.2 Effects of the energy tax reform on indicators of energy affordability

This section develops the following insights from the simulation exercise. First, combining an energy tax increase with income-tested compensation using one third of the change in revenues raised, can improve energy affordability. Second, according to the most selective energy affordability indicator (LIHCS), energy affordability can also improve when a third of the revenues is recycled in the form of a uniform lump-sum transfer.

Figure 3 shows the percentage change in the share of households facing energy affordability risk due to the reform, for the three indicators (TPR, RPL, and LIHCS), and for the income-tested and lump sum recycling options, assuming households do not change demand in response to the price changes. Using a third of the additional revenues from higher energy taxes to fund an income-tested cash transfer reduces the share of households spending more than 10% of their disposable income on domestic energy in almost all countries covered.[12] The average decrease is 4.8%, across countries (Figure 3, left-hand panel). The change in the relative poverty line indicator is comparatively small (the average decline is 0.3%), with the share of households falling below the poverty line after energy expenditure decreasing strongly only in the Czech Republic (by 6.1%; Figure 3, middle panel). The change of the low-income high-cost-share to the reform is the strongest on average, with the share of households facing difficulties decreasing by 5.8% (Figure 3, right-hand panel).

If a third of the additional revenues is transferred to households as a lump-sum transfer, the results are different for TPR and RPL. The share of households spending more than 10% of their disposable income on energy now increases by 10.3% on average, showing that the lump-sum transfer is not sufficient for many low-income households to keep expenditures below the 10% threshold. However, there is substantial variation across countries, with almost no change in the share of households with high energy expenditures in Germany, Hungary and Slovakia, but strong increases in Luxembourg (though from a very low base, see Figure 1) and the United Kingdom. In both countries, the reform implies relatively large energy price increases (see Table 3), so that expenditure shares rise strongly at lower incomes if transfers are uniform. The RPL indicator now shows a 1.8% increase in the number of households that fall below the poverty line after expenditure on energy, as opposed to the 0.3% decline with the targeted transfer.

Perhaps surprisingly at first sight, the changes in energy affordability risk as measured by the low-income high-cost-share (LIHCS) are not very different between the two types of revenue-recycling, with a significant decrease in the share of households facing difficulties in both cases. This is different from the behaviour of TPR and RPL. To see why this is so, LIHCS – in contrast to TPR – excludes households that

11. For each country, micro-data was available for one point in time only. Price elasticities based on variation of energy prices across time can hence not be estimated and thus values in line with the literature have been assumed.

12. There is hardly any response to the reform in Finland. As Table 3 reveals, this is because the reform hardly affects energy prices. Similarly, energy prices decrease in response to the reform in the Netherlands. This results in small increases in the share of households that face challenges in affording energy as transfers to poor households decrease.

do not fall below the poverty line after expenditures on energy, even if they spend more than 10% of their income on energy. These households have relatively higher incomes, so 10% or more translates into higher absolute spending on energy – spending that is high enough that a uniform transfer is insufficient compensation, which results in increased energy affordability problems under TPR (but not under LIHCS, as these households are excluded from this indicator).

Among the three indicators, LIHCS is the most selective for classifying a household as facing energy affordability risk. Compared to the TPR, households with relatively higher disposable income are not included, and compared to the RPL, only those households that have high expenditures on energy are selected. This selectivity has appeal, not because of the stringency that appears to result from it (small changes to the other indicators could make them more stringent) but because it results from the simultaneous consideration of expenditure and relative income. The potential policy implication is that (simpler) lump-sum recycling mechanisms manage to turn adverse impacts of higher energy prices into reduced energy affordability risk as effectively as (more complicated) income-tested transfers.

Figure 3. An income-tested benefit can improve energy affordability

Percentage change in households facing difficulties in affording energy according to:

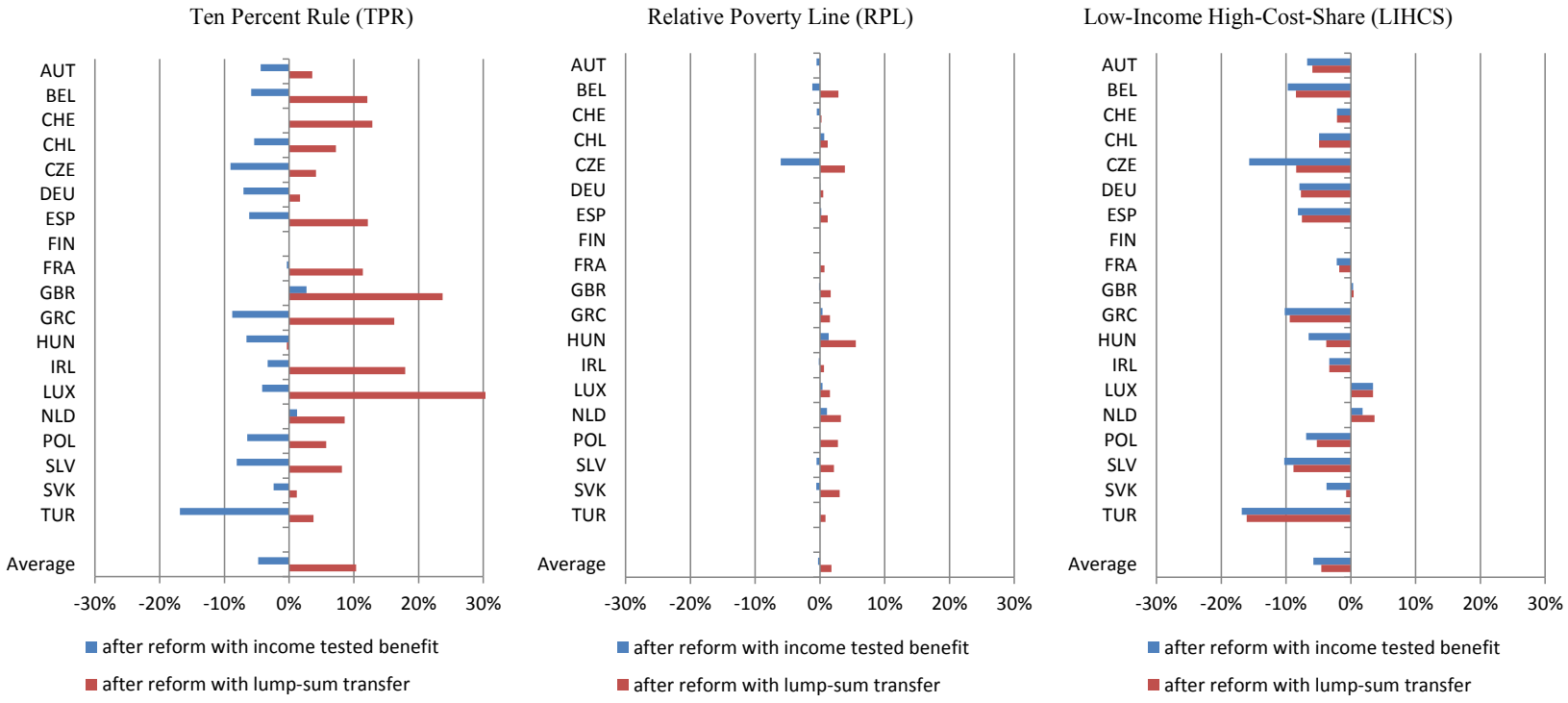
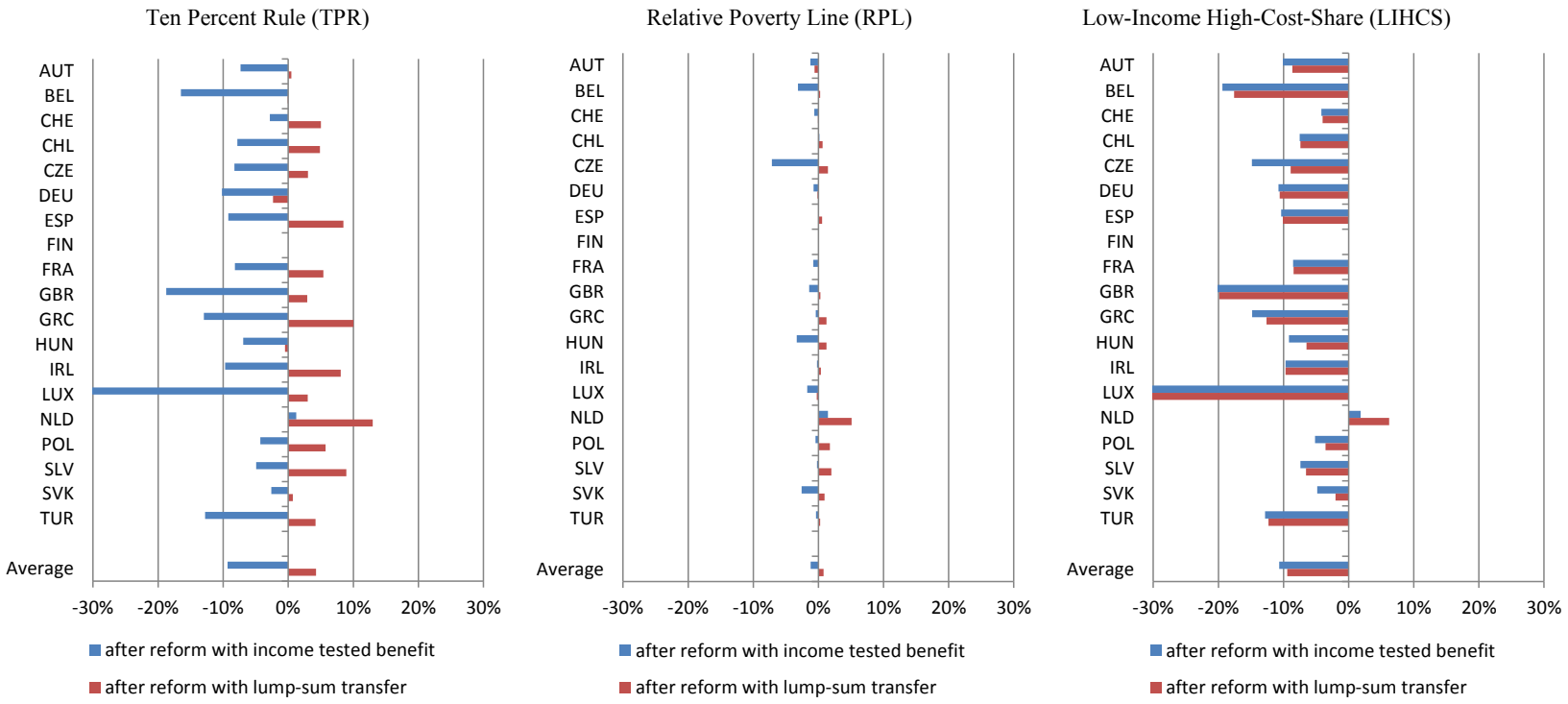


Figure 4. Accounting for behavioural responses, the share of households facing problems to afford energy declines when compared to the static case

Percentage change in households facing difficulties in affording energy after behavioural responses according to:



Turning to Figure 4, where household demand is price responsive as opposed to fixed as assumed in Figure 3, the main insight is that the TPR now measures stronger reductions in energy affordability risk, or weaker increases, compared to the fixed demand case. With the income-tested benefit, the average decrease in the share of households with high domestic energy expenditure is 9.3%. Strong decreases are particularly observed for countries where energy prices increase substantially, that is for Luxembourg, the United Kingdom and Belgium. To see why this is so, consider that the change in energy expenditure shares (for given total expenditure) after an energy price increase is smaller when demand declines compared to where it is constant. These smaller increases mean that less compensation is required to keep energy affordability risk constant under elastic demand. Revenues collected decline as well compared to the fixed demand case (because reduced demand means a smaller tax base), but this decline is smaller in absolute terms than the reduced need for compensation. This is because the revenue decline is determined by the change in demand multiplied by the tax rate, whereas the decline in expenditures is determined by the change in demand multiplied by the price. Since the price is higher than the tax, the expenditures (which determine the need for compensation) fall by more than the revenues (which determine the capacity to compensate).

The RPL indicator is fairly stable also when accounting for behavioural responses of households. On average the share of households falling below the poverty line decreases by 1.2% when households receive an income tested benefit. The LIHCS behaves fairly similar to the TPR. On average, the share of households that face challenges to afford energy now decreases by 10.7% with an income-tested benefit.

With a lump-sum transfer, an average increase in the share of households spending more than 10% of disposable income on domestic energy is still observed (4.3%), but the increase is substantially lower compared to the setting that does not take any behavioural adjustments into account. For Germany, no increase is observed at all, reflecting that behavioural adjustments of low-income households in combination with the lump-sum transfer are sufficient to outweigh energy price increases. Once more, the relative poverty line indicator hardly changes, increasing on average by 0.8%.

Similar to the fixed demand setting, the low-income high-cost-share indicator shows an improvement in energy affordability with a lump-sum transfer in the setting that allows for behavioural responses, and for the same reasons except that, in addition, behavioural responses decrease energy use and spending on energy. As a result, the share of households that face problems in affording energy decreases by 9.4% on average.

For the elastic demand setting, it has been assumed for simplicity that energy price elasticities are constant across income. However, there is evidence (Schulte and Heindl, 2017; Fouquet, 2014; Calvet and Marical, 2011) that poor and rich households respond less strongly to energy price changes than households around the middle of the income distribution. This may be because poorer households face budget and credit constraints, limiting their ability to invest in highly energy-efficient appliances, and because higher-income households are less inclined to cut demand as prices rise. If poor households responded less strongly to energy prices than in the current simulation that takes into account behavioural responses, they would spend a relatively higher share of their income on domestic energy than currently simulated. As a result, the increases in energy affordability observed when taking behavioural responses into account would also decline.

The analysis up to now has worked with deciles defined in income terms. Alternatively, they can be defined in expenditure terms. OECD (2014b) and Flues and Thomas (2015) discuss the benefits and drawbacks of both approaches. Using an income basis allows for direct comparison of the effects of

consumption taxes to taxes that are levied on an income base. Furthermore, transfers are calculated on an income basis, making income the usual choice when looking at the distributional effects of transfers.[13]

For the affordability analysis, using expenditure deciles instead of income deciles barely affects results on average. However, the income-tested transfer is less well targeted across expenditure deciles than across income deciles, so that compensation aligns less closely with expenditure than with income and reductions in affordability risk are smaller. In the static model without behavioural changes, the income-tested cash transfer leaves the share of households that spend more than 10% of their disposable income on domestic energy largely unaffected; an average increase of 1.1% is observed (Table 4). Allowing for behavioural responses, the share of households spending more than 10% of disposable income on domestic energy decreases by 2.9%. The RPL and the LIHCS indicators also hardly change in the static setting. On average small increases in the share of households facing energy affordability risk are observed (1.1% and 1.5%). When households adjust their energy use in response to price changes, these shares decline marginally by 0.2% and 2.7%.

Table 4. Change in share of households subject to affordability risk – deciles defined on an expenditure basis

After reform with income-tested benefit

Affordability Indicator	Static model	Accounting for behavioural responses
TPR	1.1%	-2.9%
RPL	1.1%	-0.2%
LIHCS	1.5%	-2.7%

4.3. Broadening the perspective: affordability, equity and welfare

Energy affordability indicators measure whether absolute spending on heating and electricity, often relative to or adjusted for income, constrains households so much in their consumption choices that any additional spending on energy poses a problem to them. Affordability of energy is a key policy concern. Raising energy prices can make good environmental sense, but should not lead to increased affordability risk when the policy reform is viewed in its totality. The simulations discussed in the previous section indicated that using part of the extra revenues from higher taxes can avoid increased energy affordability risk and even reduce it if sufficient revenue is allocated. But concerns about the impact of higher energy taxes on households can be broader. For example, if such taxes were to be regressive across the income distribution, that could reduce acceptance. The analysis of equity includes distributional effects and focuses on how much different income or expenditure groups contribute to total energy tax revenues.

Analysing existing energy taxes, Flues and Thomas (2015) find that the distributional effects of energy taxes differ by energy carrier. Taxes on transport fuels are often proportional in high-income countries and progressive in middle-income countries, looking at the same sample of mainly European OECD economies, including Estonia in addition. Cases studies in low-income countries also show progressive effects of taxes on transport fuels (Sterner, 2012). Some regressivity is observed for taxes on heating fuels in many countries while taxes on electricity are found to be regressive in all countries analysed. A review of more than 120 studies (OECD, 2014a) confirms this finding and notes that if all or a sufficient part of revenue from energy taxes is handed back to the consumer, it is possible to avoid negative distributional effects. Also poverty and deprivation can be decreased.

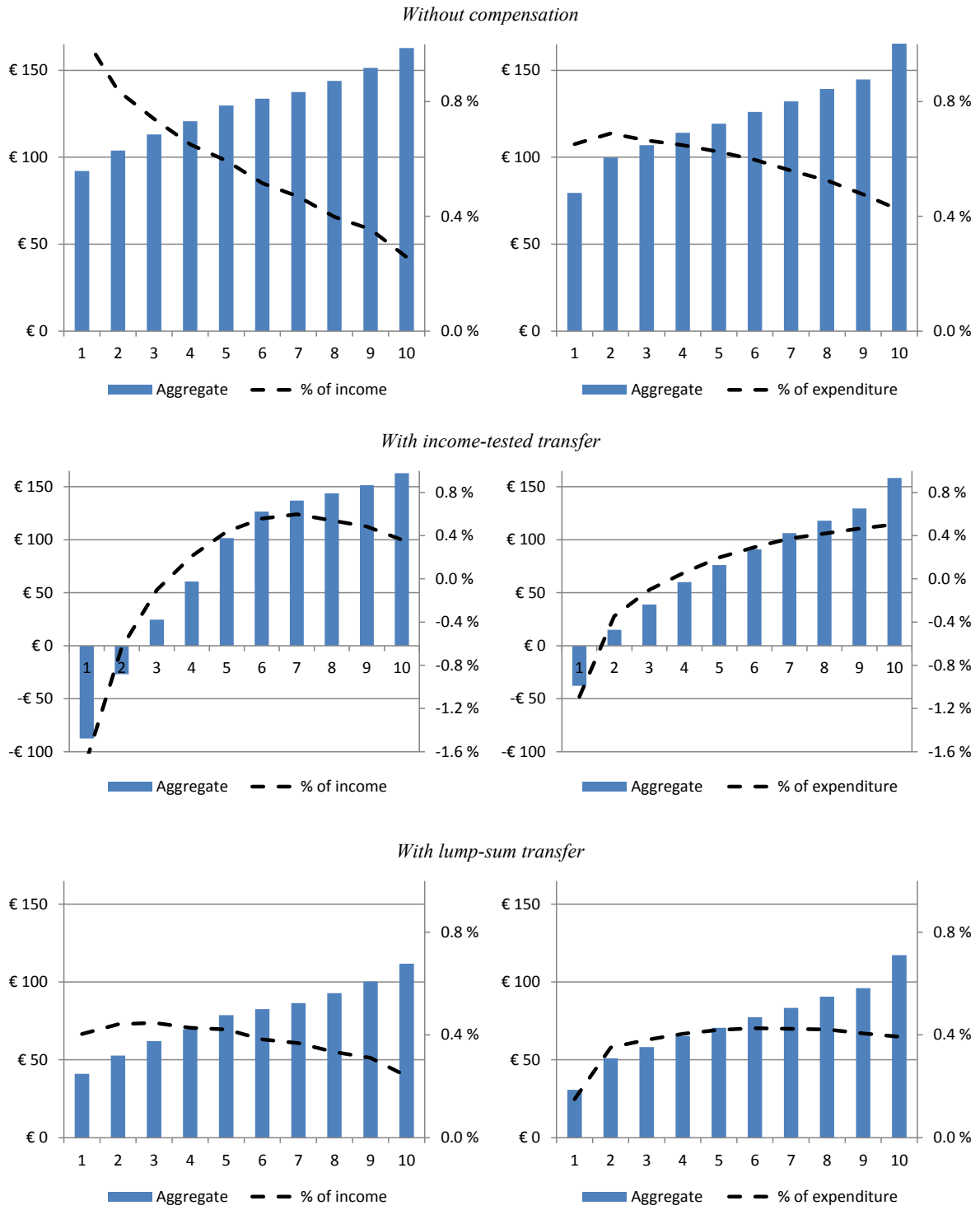
13. Nevertheless, current expenditure is a better indicator of life-time income than current income, and since utility is derived from consumption and not from income as such, expenditure is a better indicator of well-being than income.

While taxes on heating fuels and electricity are found to be regressive in many cases, overall tax contributions on these goods are low. For heating fuels, they range between 0 and 0.5% of disposable income and for electricity between close to 0 and 1% within the 21 OECD countries analysed by Flues and Thomas (2015). These low tax contributions on heating fuels and electricity hardly impact the overall distributional impact of the tax system, and therefore the argument is sometimes made that their regressive nature is not of great concern.

Looking at the distributional effects of the energy tax reform discussed in the previous section, the first row of Figure 5 shows that richer households contribute more to energy tax revenues in absolute terms than poorer households in response to the tax changes that result from the reform. Without any compensation, and not taking any behavioural adjustments into account, tax contributions will increase nearly twice as much for a household in the highest income decile than for one in the lowest income decile due to the tax changes. The same pattern holds across expenditure deciles. As a percentage of income across income deciles, poorer households clearly contribute more tax revenues than richer households due to the tax changes. Figure 5 shows clearly regressive patterns of tax changes both on an income and expenditure basis. The small increase in expenditures from the first to second expenditure decile is due to heating taxes not being regressive on an expenditure basis.

Figure 5. Rich households' energy tax contributions increase the most in response to the reform

All-country average tax difference per household from the simulated energy tax reform without demand response



Households in the lowest two income deciles are better off on average in monetary terms after the reform when accounting for the income-tested cash-transfer, as shown in the second row of Figure 5. This also holds for households in the lowest expenditure decile. The stronger change on an income basis compared to an expenditure basis is not surprising given that the transfer is income-tested and that some

low-income households have substantially higher expenditure and vice versa. Overall these results confirm the findings from the analysis of energy affordability, namely that poor households can benefit from an appropriately designed energy tax reform.

The simulated income-tested cash-transfer ensures that the impact of the reform falls more on richer households than on poorer households both in absolute terms and in relative terms. On an income basis, the tax contribution increases from the first to the seventh decile, and stabilises from there onwards. On an expenditure basis, the tax reform is clearly progressive across the whole expenditure distribution.

The simulated lump-sum transfer increases the difference in tax contribution changes from the reform between poor and rich households when compared to the reform without any compensation as seen in the third row of Figure 5. This is because every household receives the same absolute relief per person. Poor households still contribute more on average than without the reform, but substantially less than richer households. As a percentage of income across income deciles the change in tax contributions is somewhat regressive, but considerably less so than without any transfer. On an expenditure basis, the tax reform is largely proportional and tax contributions even increase noticeably for households in the second expenditure deciles when compared to those in the first decile. Overall, the results show that compensation can not only mitigate adverse impacts of higher energy taxes on energy affordability, but also helps avoid regressivity or can undo it.

Accounting for behavioural responses will not change the distributional impacts of the reform as long as elasticities are constant across income, as it is assumed in the simulations. While absolute tax contributions will decline, this decline will be proportional. Lower elasticities for rich compared to other households would lead to more progressive effects of the tax reform, while lower elasticities for poor households would lead to more regressive effects. Schulte and Heindl (2017) find that elasticities are lower for poor than for richer households in Germany. If this held true for all countries, the impact of the reform would be less progressive than modelled and shown in Figure 5. In other words, more support for poor households than currently modelled would be needed to arrive at the distributional patterns shown.

While affordability and equity are important considerations in policy debate, the impact of a tax reform on household welfare – understood in its microeconomic sense of the net benefits drawn from expenditure – arguably is the key concern. Unfortunately, a full analysis of the welfare impacts is not possible with the available modelling tools, given their lack of a comprehensive and consistent specification of prices and of demand. A very rough approximation, however, can be made by considering how the reform affects households' real budgets. The household budget increases by the amount of transfers received but declines in real terms because energy prices are higher (and not all revenue is recycled).[14] If demand is (more or less) fixed across the consumption bundle, then the real budget is a reasonable approximation of the change in welfare.[15] Since the full price vector is not known (the available data describe expenditures, not all prices), the price index needs to be approximated. Here, the reference price index is set at one, and the impact of the reform is approximated by multiplying the reference price index with the percentage price change of heating and energy weighted by their respective expenditure shares.

14. While this paper looks at whether one third of the additional revenue is sufficient to make poor households better off in response to an energy tax reform, it should not be forgotten that the remaining two-thirds of the additional revenue, as well as the changes in emissions that result from the energy tax reform, will have additional impacts on welfare.

15. More precisely, since behavioural responses to income changes would reduce welfare losses or increase welfare gains, the fixed demand assumption is a lower bound to welfare increases and upper bound to welfare losses.

Table 5 summarises the changes in households' real incomes in response to the tax reform. The increase in the price index is small, so that the results mainly depend on the transfers. Without transfers, real income declines by about 0.9% (EUR 90) for a household in the lowest decile and by 0.3% (EUR 170) in the highest decile. Under the income-tested transfer, households' real budgets increase on average for the lowest two income deciles (by 0.9% in the lowest decile and by 0.2% in the second decile). The lump-sum transfer counteracts the decline in real incomes, but not completely: a household in the lowest income decile has on average 0.4% (EUR 40) less to spend.

The information from the real disposable income metric is similar to that of the TPR. Both identify a worsening of the situation of the lowest deciles even after accounting for lump sum transfers, and both capture an improvement in the lowest deciles if income-tested transfers are used (although in decile 3, real income still declines with income-tested transfers). The LIHCS shows a different result, in that it also finds an improvement of energy affordability with lump sum transfers. The compensation may be insufficient to mitigate the effect of higher energy prices across the income distribution, but it is sufficient to make energy more affordable. Also in this sense, LIHCS is a more stringent indicator of affordability than the other indicators.

Table 5. Households' real budgets increase for the lowest quintile with an income-tested transfer

Income Decile	Real disposable income (EUR/year)				% change		
	Before reform	After reform without transfer	After reform with income-tested transfer	After reform with lump-sum transfer	After reform without transfer	After reform with income-tested transfer	After reform with lump-sum transfer
1	9961	9870	10049	9921	-0.92%	0.89%	-0.40%
2	13680	13576	13706	13627	-0.77%	0.19%	-0.39%
3	17065	16950	17032	17001	-0.68%	-0.20%	-0.38%
4	19965	19841	19897	19892	-0.62%	-0.34%	-0.37%
5	23403	23269	23292	23320	-0.57%	-0.48%	-0.35%
6	26769	26630	26611	26681	-0.52%	-0.59%	-0.33%
7	30288	30145	30146	30196	-0.47%	-0.47%	-0.30%
8	35361	35211	35211	35262	-0.42%	-0.42%	-0.28%
9	41708	41550	41550	41601	-0.38%	-0.38%	-0.26%
10	62966	62795	62795	62846	-0.27%	-0.27%	-0.19%

5. Summary and conclusion

This paper analysed the impacts of energy taxes on energy affordability. Energy affordability relates to absolute levels of expenditure on heating fuels and electricity, often in relation to income. High expenditures on domestic energy may constrain poor households substantially in their consumption choices. This may lead to inadequate levels of electricity and heating use, possibly compromising health and normal activity patterns. Five findings emerge from the analysis of energy affordability.

First, the share of households that face energy affordability risk varies largely across countries, between 2.3% and 30.1% in the sample of 20, mostly European, OECD countries. The countries with the highest GDP per capita tend to also have the highest levels of energy affordability. High shares of households facing challenges to afford energy are mostly observed in Central European countries.

The paper compared three indicators of energy affordability that meet basic consistency requirements. A second finding is that the incidence of energy affordability problems differs between them. Among the three indicators, the LIHCS indicator is the most restrictive in identifying a household as facing challenges to afford energy. This is by construction, as the LIHCS is a combination of the other two indicators,

namely the TPR and the RPL. In many countries, the LIHCS indicator shows results that are fairly close to that of the TPR.

Third, looking at potential determinants of energy affordability, countries with higher GDP per capita tend to have higher energy affordability. In contrast, higher energy taxes or prices do not correlate with lower energy affordability. One potential explanation for the latter observation is that higher energy prices over time lead to higher energy efficiency, so mitigating the effects of higher costs per unit of energy. Another possibility is that countries that might expect that high energy prices would particularly harm poor households, try to keep them low.

A fourth finding is that a reform that increases taxes on heating fuels and electricity can reduce energy affordability risk if parts of the additional revenues are transferred back to households using an income-tested cash transfer. In many countries, transferring a third of the additional revenues to poor households is sufficient to reduce energy affordability risk. With a uniform lump-sum transfer to all households, energy affordability only improves according to the LIHCS indicator, while it declines as measured by the TPR and the RPL. Real income also increases for the lowest two deciles when governments provide income-tested transfers.

Fifth, while richer households are affected more by an increase in taxes on domestic energy in absolute terms, such taxes are still likely to be regressive if no additional policy measures are implemented. Lump-sum transfers can mitigate regressive impacts, while income-tested transfers can result in a progressive impact of the tax reform.

A more general distributional analysis could not only consider the direct impacts of energy taxes and transfers, but also try to take co-benefits of tax reform into account. For example, higher taxes on energy likely improve health by reducing air pollution. This can in turn boost labour productivity and reduce costs for medical treatments. Poor people may be prone to living in areas with high air pollution and thus benefit the most from a better air quality caused by cleaner and more efficient energy use. This can be an important progressive element of energy taxation, which may offset the above mentioned regressive impacts at least partly.

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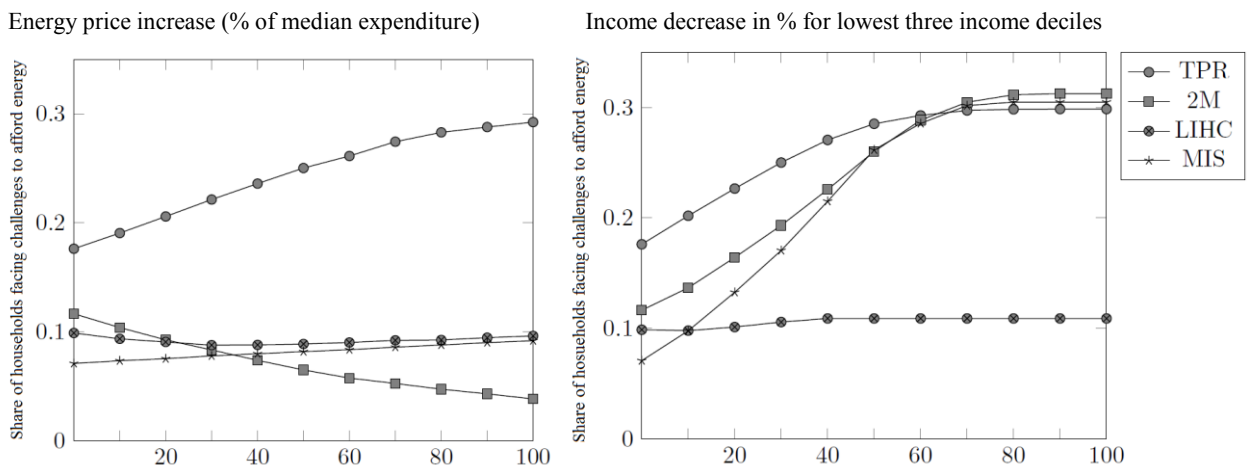
Annex A

PROPERTIES OF ENERGY AFFORDABILITY INDICATORS

Simulations of energy price changes for Germany described in Heindl and Schüssler (2015) show how the double median (2M) and the LIHC indicators can measure an improvement in energy affordability when energy prices increase and thus fail the *position invariant burdening* criterion; see the left panel of Figure A.1. The double median indicator, for example, consistently declines in response to an increase in energy prices that is proportional to income, irrespective of the size of the price increase. Also the LIHC standard shows a supposed increase in energy affordability in response two moderate proportional increases in energy price.

Figure A.1. Response of energy affordability measures to price and income changes



Notes: TPR - Ten Percent Rule, 2M – Double Median, LIHC – Low-Income High-Cost, MIS – Minimum Income Standard (absolute poverty line)

Sources: Adapted from Heindl and Schüssler, 2015.

Simulations for income changes show the LIHC indicator can fail the *impoverishment* criterion (Figure A.1, right panel). More precisely, in a scenario where income falls for the lowest three deciles and stays the same for the higher income deciles, the LIHC fails to show a decrease in energy affordability for income decreases larger than 30% (Heindl and Schüssler, 2015). Households that spend less than the median on domestic energy, i.e. half of all households, can never face problems to afford energy according to the LIHC, even if their income is so low that they practically cannot afford buying any energy services at all.

Figure A.1 also displays the TPR and the Minimum Income Standard (MIS). The MIS measures whether households fall below the absolute poverty line after energy expenditures. In Germany, the absolute poverty line is determined by the costs for a basket of goods that a typical low-income household consumes. Both indicators show a deterioration in energy affordability in response to an increase in energy prices or a decrease in income, as one can reasonably expect from indicators of energy affordability.

Annex B

METHODOLOGY AND DATA

The analysis of energy affordability indicators and their response to tax reform uses expenditure micro-data from household budget surveys (HBSs) to calculate domestic energy expenditures and to model energy taxes. The HBSs are sample surveys of households carried out periodically by National Statistical Offices. They provide detailed information on household consumption expenditure on goods and services, possession of durable goods and housing. They include demographic and socio-economic characteristics of the surveyed households, including disposable income. Regarding domestic energy use, household expenditures for heating fuels and electricity are used.

To enhance consistency across countries, the standardised Eurostat-format HBS micro-data is used. Micro-data from non-European Union countries is adjusted to approximate the Eurostat-format as closely as possible. The homogenised format allows a standard model to be developed and applied to each country, rather than requiring country-specific models. While the micro-data is not generally publicly available, data was provided specifically for the analysis of consumption and energy taxes by the respective national statistical offices.

Countries provide the Eurostat-format HBS micro-data to Eurostat once every five-years. The data in the most recent data-provision cycle relates to various years from 2008 to 2012.[16] The countries modelled in this paper where data was provided in the Eurostat-format (with year in parenthesis) are: Finland (2012); France (2011); Belgium, the Czech Republic, Greece, Hungary, Luxembourg, Italy[17], Poland, the Slovak Republic, Slovenia, Spain (2010); Austria (2009); Germany (2008); Ireland and the Netherlands (2004). Data for the latter two countries relates to the previous Eurostat data-provision round. In addition, non-standardised data has been obtained for Chile (2012), Switzerland (2011)[18], Turkey and the United Kingdom (2010).

Energy tax reforms are simulated applying the micro-simulation model for consumption and energy taxes developed within the Centre for Tax Policy and Administration. The micro-simulation model calculates tax contributions for individual households, average tax contributions across equivalised[19] net income and equivalised pre-tax expenditure deciles, and the aggregate population. The model is constructed by matching energy expenditure data to its corresponding rates (valued added taxes (VAT),

16. When examining results for countries for which the HBS dates back several years one should bear in mind that expenditure patterns may have changed. In particular forecasts based on such data may be inaccurate.

17. Note that the data for Italy does not include an income variable which limits some of the analysis that can be undertaken for the country.

18. Note that the data for Switzerland is derived from three separate surveys for 2009, 2010 and 2011.

19. The "OECD-modified" scale for "equivalised" income provides a weight of 1 for the first adult household member, 0.5 for the second and each additional household member aged 14 and over, and 0.3 for each child under 14. Pre-tax income is divided by the total family weight to determine the family's "equivalised" income. The same procedure is applied to expenditure to calculate "equivalised" expenditure.

excise duties on energy and tradable emission permit prices).[20] A micro-simulation programme then calculates the amount of VAT, as well as excise duties and permit prices paid by each household by applying the tax rates to the corresponding expenditure amounts. The simulation order is, first, *ad quantum* excises and permit prices, and, second, VAT. This is the approach taken by all countries currently covered, and means that each tax (or carbon rate) base includes the amounts of the previous tax (or carbon rate). Reforms in this paper only apply to *ad quantum* excise duties and permit prices.

The model attributes the entire consumption tax and emission permit price incidence to the final consumer. This is a standard assumption made in most consumption tax studies (see, e.g. IFS, 2011; Leahy, Lyons and Tol, 2011; Decoster et al., 2010). However, it should be noted that consumption taxes and emission permits may in some cases be less than fully (or even more than fully) passed on to consumers.[21]

Further methodological details are described in OECD (2014b) and Flues and Thomas (2015). For the purpose of this paper, it is worth noting that micro-simulations do not need to be carried out for deriving the total expenditure on domestic energy in Section 5, as data for expenditures on heating fuels and electricity is directly available from household budget surveys.

20. In addition to excise duties tradable emission permit prices are mapped into effective carbon rates on energy for all countries that take part in the European Union Emissions Trading System (EU ETS). In these countries emission permits are required for the generation of electricity, but not for the generation of heat by households.

21. IHS (2011) discusses the theoretical and empirical literature on pass-through of VAT and excise taxes. Bushnell et al. (2013), Fabra and Reguant (2013) and Sijm et al. (2006) estimate cost pass-through of carbon emission permits in electricity markets.

Annex C

SHARE OF NATURAL GAS AND HEATING OIL IN TOTAL HEATING FUELS

Table C.1 shows the share of natural gas and heating oil in total heating fuels by country for the year of the HBS (See Annex B for more information). While the share in eight countries are close to 80% or more, it is only at 8% in Finland where district heating and solid heating fuels dominate, and 30% in Turkey which uses a high share of solid heating fuels. On a simple country average natural gas and heating oil account for 66% of heating fuels.

Table C.1 Share of natural gas and heating oil in total heating fuels

Country	Share of natural gas and heating oil in total heating fuels
AUT	49%
BEL	94%
CHE	50%
CHL	83%
CZE	51%
DEU	68%
ESP	83%
EST	24%
FIN	8%
FRA	79%
GBR	97%
GRC	84%
HUN	59%
IRL	67%
ITA	83%
LUX	92%
NLD	91%
POL	41%
SLV	52%
SVK	61%
TUR	30%