The evolution and implications of national energy cost shares

Paolo Agnolucci[1,2], Vincenzo De Lipsis[2,3], Defne Gencer[4], Abraham Lartey[5], and Michael Grubb[2]

Abstract

Energy consumption has gained renewed prominence given its primary role in the global effort to mitigate climate change and, more recently, due to the ongoing Russian invasion of Ukraine. Energy cost share, which is the energy cost for the final consumers as a share of total economic output, is an indicator that is useful for many purposes: to assess the importance of energy in an economy, to highlight the potential exposure of energy-importing countries to international price shocks, and to understand the implications for the national economy of introducing carbon pricing or energy subsidies reforms. This study draws upon a dataset covering 142 countries over a period of up to 40 years, from 1980 to 2019. National energy costs were computed by multiplying prices by demand across a wide range of fuels consumed in the industrial, residential, service, and transportation sectors. Three types of analysis were performed: a descriptive study of the historical patterns of energy cost shares and energy prices to explore potential co-movements in these two variables; an econometric estimation of the dynamic elasticity of energy cost share with respect to economic activity and energy prices; an assessment of the influence of a wide set of energy efficiency policies and key national economic characteristics on the responsiveness of energy cost share to energy price changes. Estimates of the dynamic coefficients and the timing of the adjustment process are used to discuss the implications of energy subsidy reforms.

[1] Prospects Group, World Bank
[2] Institute for Sustainable Resources, University College London
[3] Department of Economics, University of Southampton
[4] ESMAP, World Bank
[5] Department of Economics, School of Oriental and African Studies, University of London

1. Overview

Falling energy cost shares, the ratio of energy costs to GDP, is widely considered a stylized fact in the energy literature, though long-run empirical studies have been documented only for Sweden and the UK over 1800-2009, and the USA in 1950-1998 (Csereklyei et al. 2016; Jones 2002; Stern and Kander 2012). The interest of policymakers in energy cost shares is motivated by several considerations, given the critical role of energy for economic activity and the daily lives of citizens. High energy costs, in Europe but also in many emerging markets and developing economies (EMDEs), have recently been under scrutiny with a number of policies introduced by governments to shield households and firms (Sgaravatti et al. 2021). High energy costs have implications for economic growth and inflation, especially when they are the result of sudden supply shocks to the economy, as in the 2022 crisis (WB 2022a).

Energy cost shares are also important in the context of energy subsidies, which have several negative consequences related to distortions of relative prices, increasing energy consumption and environmental impacts, reduction of incentives for adoption of alternative energy sources and energy efficiency, misallocation of resources towards those benefitting the most from reduced energy prices, and increasing public deficit leading to higher levels of debt or higher taxation, with related negative impacts on economic growth (Koplow and Dernbach 2001; Plante 2014; Yau and Chen 2021).[6]

From a policy perspective, the response of energy cost shares is also relevant to understand how direct or indirect carbon pricing (Agnolucci et al. 2023, Agnolucci et al. 2024, OECD 2022) can incentivize changes in technologies, capital stock, economic structure, and consumption behaviour, which enable the realization of climate targets. Like in the case of energy subsidy reforms, efforts to increase energy prices by introducing environmental taxes can be met with public reaction and political pushback in both EMDEs and advanced economies (AEs) (Lee 1994, OECD 2006, Skovgaard et al. 2019).

Studying how energy cost shares respond to energy prices helps us understand to what extent an economy or a specific sector is affected by various policies related to energy pricing, taxation, or carbon pricing. But it also helps inform the design of pricing policies and additional measures that can support their implementation, such as measures aimed at compensating those who are worst impacted.

[6] Empirical evidence overwhelmingly supports the existence of a long-run negative impact of public debt on GDP, and in many cases the impact becomes more pronounced as debt increases (de Rugy and Salmon 2020; Eberhardt and Presbitero 2015.) Similarly, the impact of taxes on economic growth is highly non-linear, with negative impact of tax increases becoming increasingly negative as the tax rates increase (Gunter et al.2021)The impact is influenced not only by the overall level of the taxation but also the type of taxation (Arnold 2008, Nguyen et al.2021).

This paper delivers the first rigorous study of the global evolution of energy cost share using national data from a vast set of countries. This includes an assessment of how energy cost shares have evolved over time, using a large dataset encompassing several EMDEs, alongside AEs, and an in-depth econometric exploration of the relationship between energy cost shares and energy prices. The analysis is based on data from 142 countries over a period of up to 40 years (from 1980, subject to national data availability), taking account of existing country-specific heterogeneities and capturing the timescale of the estimated effects. It also assesses the impact of a number of key national economic characteristics and a wide set of energy efficiency policies on the relationship between energy cost shares and energy prices, therefore offering a rich set of insights to governments considering the introduction of energy subsidy reform.

2. Methods

Energy cost share in this paper is modelled as a function of energy price and economic activity, as well as a set of time-invariant factors that are specific to each of the countries included in the dataset. We incorporate a partial adjustment model by estimating the following equation

$$cs_{it} = \mu_i + \rho_1 cs_{it-1} + \sum_{j=0}^{T} \alpha_j ep_{it-j} + \beta_1 y_{it-1} + \varepsilon_{it} \qquad (1)$$

where cs_{it} indicates the energy cost share for country *i* at time *t*, ep_{it} indicates the prevailing energy price, and y_{it} indicates the level of economic activity. The term μ_i is a fixed-effects component for country *i* and ε_{it} is an idiosyncratic error. Energy cost share is defined as the product of energy price and energy consumption, divided by the level of economic activity, $cs_{it} = (ec_{it} \cdot ep_{it})/y_{it}$. The model above is estimated for the whole set of countries in the dataset as well as for groups of countries identified based on the value of economic factors poised to influence the relationship between energy prices and cost shares.

We explore the influence produced by existing energy efficiency policies on the relationship between energy price and energy cost share by augmenting equation (1) with a set of indices of energy efficiency developed by the World Bank (2022b). These indices are part of the Regulatory Indicators of Sustainable Energy (RISE). One at a time, each of these indices is interacted with the level of energy price to allow for the impact of price on energy cost share to be mediated by the level of energy efficiency. The new equation augmented with the efficiency index eff_i becomes

$$cs_{it} = \mu_i + \rho_1 cs_{it-1} + \sum_{j=0}^{T} \alpha_j ep_{it-j} + \gamma_0 ep_{it} \cdot eff_i + \beta_1 y_{it-1} + \varepsilon_{it}. \qquad (2)$$

This equation allows for a potential discrepancy in the contemporaneous impact of energy price on energy cost share between high-efficiency and low-efficiency countries, captured by γ_0, a quantity which can be positive, negative, or zero.

Both equations (1) and (2) above are estimated using the system Generalized Method of Moments (GMM) estimator (Arellano and Bond 1991; Blundell and Bond 1998) to overcome the bias in the estimation of dynamic panel models (Nickell, 1981).We implement the forward orthogonal deviation transformation, which is an alternative strategy to the first-differencing used in Arellano and Bover (1995), as it is resilient to missing data, therefore preserving sample size in panels with gaps. Standard errors are calculated by incorporating the small sample correction developed by Windmeijer (2005) for the two-step estimator, improving on the implausibly small standard errors, which would be otherwise computed.

3. Data

For the analysis performed in this paper, energy consumption and price data were collected for fuels consumed in most of the sectors of a given economy and aggregated to compute total energy consumption for each country and related energy price. Real GDP in international (Purchasing Power Parity or PPP) dollars was computed using data from IMF (2023). Data from energy balances published in IEA (2022) and WB and IMF (2024) are used to determine the total amount of energy consumed in each country. Annual retail prices for the fuels included in this study are sourced from the datasets underlying Parry et al.(2021) and WB and IMF (2024).

The impact of energy efficiency *policies* on the relationship between energy price and energy costs shares is assessed using energy efficiency indices from WB (2022b).This study employs multiple indicators of country characteristics to examine how the estimated impacts differ across factors that could potentially affect the response of energy cost shares to changes in energy prices. These include: 1) the *stage of economic development* according to the World Bank's income classification (WB 2024); 2) the *degree of financial development* as measured by the index introduced by Svirydzenka (2016); 3) the *human capital index* developed by Kraay (2019); 4) The *oil trading status*, as computed in Agnolucci et al.(2024); 5) The degree of dependence on *energy imports* defined as net energy imports as a percentage of energy use, taken from the World Integrated Trade Solution (WB, UNCTAD, WTO and UN, 2024); 6) The level of *net energy consumption taxes,* as computed in Agnolucci et al.(2024).

4. Results

This work focuses upon how consumer energy prices impact the energy cost shares, i.e. the ratio between energy costs and GDP, in the context of other influences such as stage of economic development, financial development, oil and energy trading, and energy efficiency policies. We have conducted an extensive econometric analysis to disentangle these factors. A number of conclusions, relevant for both economic analysis and policy design, can be drawn from this work.

First, as expected, energy cost shares and energy prices tend to move together in the short-term, though by less than 100% even in the year when price changes take place, as countries react to higher prices by tempering energy demand. This reaction, however, gets stronger as time goes by, offsetting the initial impact of a sustained increase in energy prices since economies adapt. Moreover, the correlation between energy prices and cost shares has decreased across time: from mid 2000s up to 2019, global energy prices have fluctuated while energy cost shares have decreased. Reasons for this may include an identified contribution from energy efficiency policies, along with other policies adopted to reduce greenhouse gas (GHG) emissions. This is an important finding, as a lower correlation between energy cost shares and prices facilitates the adoption of policies increasing energy prices such as energy subsidy reforms and carbon pricing. In aggregate, we also found evidence of a long-term decrease in global energy cost shares relative to energy prices, reflecting a systematic decline in energy intensity over time. As an example, in 2019 average energy cost share in PPP terms was similar to the level observed in 1988, despite consumer energy prices increasing by more than 50 percent.

The econometric analysis in this paper points out that, as time goes by, national economies respond to a sustained increase in energy prices by reducing their national energy intensity and this response in the end offsets more than half of the price increase. A 100% increase in energy prices ultimately leads to only a 48% increase in energy cost shares. This offsetting response of energy intensity has become stronger in more recent years, to the extent that using only the data over the 2000-2019 period we estimate a 40% increase in energy cost shares in response to prices doubling. This finding, which is robust to the set of instruments used and the specification of the model, implies that increasing energy prices to facilitate the transition to low-carbon energy systems does not require an equivalent increase in the energy costs borne by final consumers.

Nevertheless, the time it takes for energy intensity to fully adjust to changes in energy prices is long. After 18 years only half of this adjustment has taken place, which means 4% each year. This reflects heavy adjustment costs in the economy, which is not surprising considering the long lifetime of energy-using capital stock that can easily reach several decades.

There are, however, major differences across countries. We found that the energy cost shares averaged over the past 40 years tend to be in the range of 6-10% of GDP for advanced economies, while energy cost shares for other countries span a much wider range. In addition, there is considerable heterogeneity in the co-movement between energy cost shares and prices across countries and sectors. In some countries, energy cost shares and energy prices have moved together throughout the timespan used in this study, while in others their co-movement has been largely counteracted by a decreasing long-run trend in energy cost share perhaps linked to technological change, policy interventions, modernization of the economy or structural changes. The same level of heterogeneity in the pattern of energy cost shares and energy prices can be found across sectors of the economy. Taken together, these two important findings show that different countries or sectors within the same country can have varying abilities to counteract the impact of energy price increases on energy costs shares. Any long-term strategy to align energy prices with the full costs, i.e. subsidy removal, environmental taxes, and carbon pricing, might need to consider varying ability of energy users to neutralize the impact of energy price increases when selecting the sectors that should be targeted first for energy subsidy reform or carbon pricing.

There are five broad conclusions relevant to policy. First, to the well-grounded economic argument for reducing energy subsidies we add the finding that removing subsidies offers a fiscal gain that exceeds the added costs to consumers; moreover, this gain will increase over time as the economy gradually responds to higher prices. Second, the full adjustment unfolds over long periods, typically one or more decades. Consequently, governments need to tackle the challenge of managing the transition towards higher energy prices and their impact on energy consumers, in particular those least able to afford the increased price of energy. Some of the fiscal gain could be used to compensate poorer households. Third, the same basic arguments apply to carbon pricing and other policies to internalize the damages associated with fossil fuel use. The economy can adjust over time to carbon prices, which helps align price signals in the economy with the growing imperative to tackle climate change. In this context, some of the fiscal surplus could also be used to accelerate the adoption of improved low carbon technologies, which in turn reduces the exposure of the economy to the impact of carbon pricing. Fourth, the introduction of energy subsidies reform can be facilitated through the introduction of a set of broader economic policies affecting the response of energy consumers to an increase in energy prices. Our analysis shows that policies stimulating economic growth, the level of financial development and human capital have all a role to play in increasing the speed of adjustment to the new long-run equilibrium and decreasing the size of the long-run response of energy cost shares with respect to energy prices. Finally, we have shown that energy efficiency policies can enhance and accelerate the structural adaptation to higher energy prices. Again, this reinforces a widely (if not universally) recognized conclusion, of the benefits of complementary policy packages, and in this case, specifically the benefits of targeted energy efficiency policies which more directly, and permanently, reduce the exposure to all forms of policies for economically appropriate energy pricing, whether subsidies, excise duties, or carbon pricing.