Energy efficiency and economic growth

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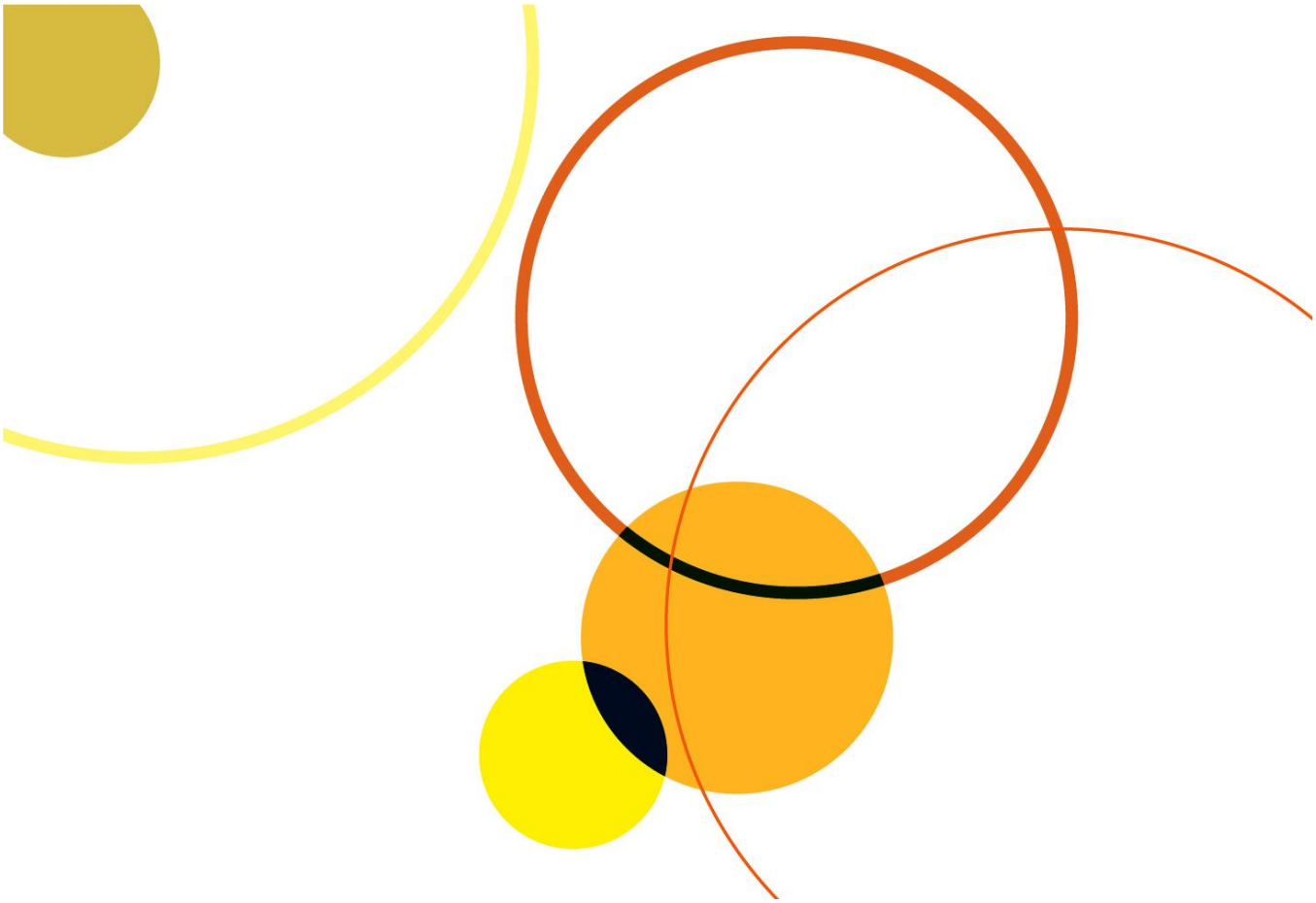


Executive Summary

Energy efficiency measures can contribute to higher economic growth

The purpose of this report is to examine the causal relationship between energy efficiency and economic growth using advanced statistical methods.

It finds that an improvement in energy efficiency can contribute to higher economic output.

The academic literature has focussed on the relationship between energy use and economic growth but less on the effects of energy efficiency measures on growth. The estimation of energy efficiency is notoriously difficult whereas energy productivity is easily observed. This analysis aims to extract the impact of energy efficiency on energy productivity and, in turn, on output.

Previous studies show that energy efficiency measures have significant potential savings associated with them and are a cost-efficient way to reduce emissions. Understanding the effect of energy efficiency measures on economic growth is a first step to fully account for the costs and benefits of such measures.

Energy efficiency improvements are found to contribute positively to economic growth for the group of 28 OECD countries over the last three decades. This does not imply that the same relationship will continue or be present for individual countries. Over the last three decades, economic growth partly decoupled from energy consumption and energy productivity, increased. The statistical analysis is based on these past results. There are two effects which can influence the results as well as its applicability in the future:

- as countries became more energy efficient over time, they moved closer to their maximum possible level of energy efficiency;
- the diverse dataset for this study spans countries at different stages of development. Low income countries usually have more potential for energy efficiency improvement as well as a naturally higher economic growth rate.

Both effects suggest that the found positive effect might not be applicable to each country individually and that the relationship might change in the future.

1 Introduction

This report investigates the relationship between energy efficiency and economic growth. Energy plays a significant role in the economy as a major factor of production. Given higher real energy prices, the efficient use of energy can contribute positively to economic growth.

Three points are to be considered when evaluating the effect of energy efficiency measures on economic growth:

- first, the relationship between energy use and economic output;
- second, the effect of energy efficiency on economic growth; and
- third, the country specific energy efficiency potential.

The first relationship between economic growth and energy use has been investigated before; however less work has been undertaken on the second and third points.[1]

This report adds to the literature by investigating the second point: what is the effect of energy efficiency on economic growth?

Related academic studies found evidence that countries, which make progress in cutting the carbon intensity of their economies, far from sacrificing economic growth, have seen growth accelerate. This provides a starting point for the analysis (Hu & Wang, 2006; Kuramochi, 2006; Miketa & Mulder, 2005; Newell, Jaffe, & Stavins, 1998). These studies consider only the reduction in carbon intensity, which is not necessarily associated with greater energy efficiency. Nevertheless, it is a first indication that energy efficiency measures might not harm economic growth.

This report is split into two parts:

- first, the background on energy, energy efficiency and economic growth, followed by an explanation of the potential of energy efficiency to contribute to economic growth and how this can be estimated; and
- second, the results of the statistical analysis for the group of 28 countries and its interpretation.

1.1 Energy and economic growth

The relationship between energy and economic growth has been the subject of many academic debates and the consensus is that energy consumption and growth are linked. For example, both Ozturk (2010) and Payne (2010) conduct meta-studies and conclude that economic output and energy consumption are linked, although the empirical evidence of causality, that is whether energy consumption drives economic output or vice versa, is mixed. Studies using multiple mathematical and statistical models and a range of different countries have further confirmed the link but reached divergent results on causality as a result of the model specification and the country analysed, see for example Costantini & Martini (2010).

[1] The energy efficiency potential for particular measures has been investigated for most developed countries. However, these are specific measures related to industries and are not an indication of the maximum energy efficiency an economy can achieve.

There is a relationship between economic growth and energy productivity but there could be causation in both directions as shown by previous studies. For example:

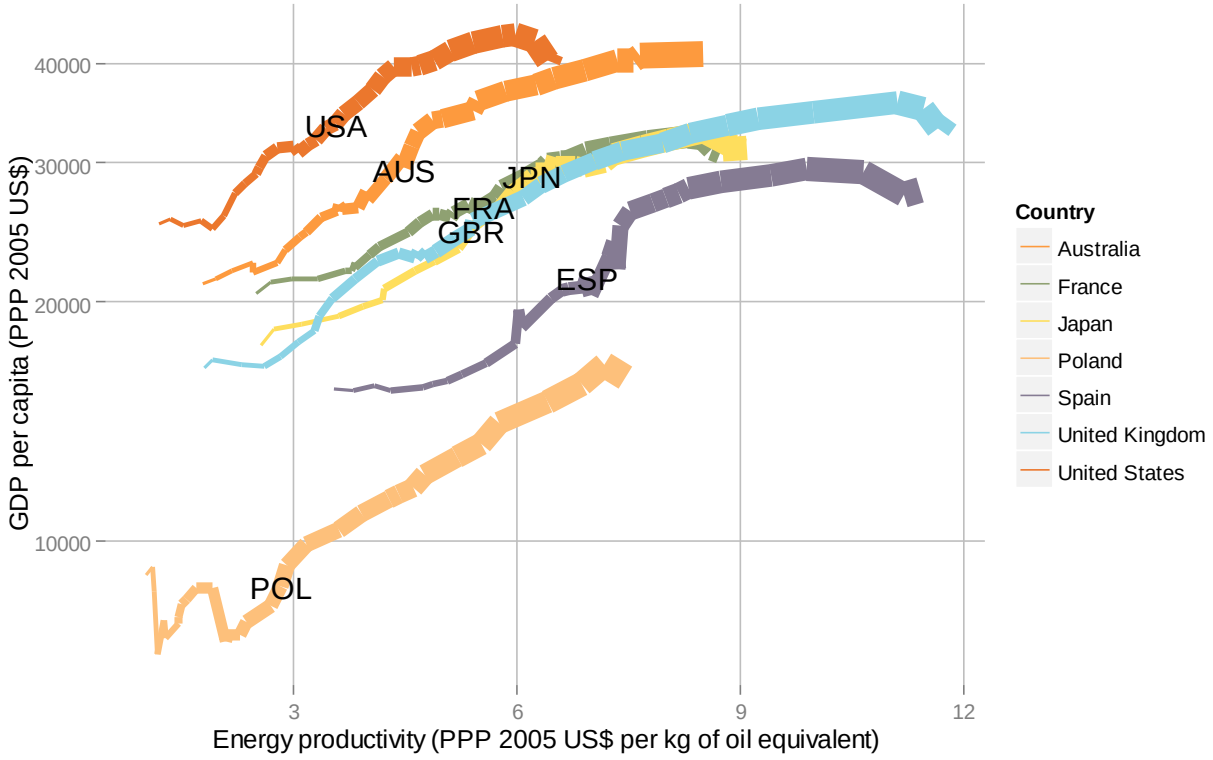
- energy efficiency reduces production costs which boosts factor productivity and therefore growth; and
- economic growth may lead to an increase in the share of less energy-intensive sectors, such as financial services, increasing observed energy productivity in an economy.

Although the relationship between energy and economic growth has been investigated, there is little academic literature on the effects of energy efficiency on economic growth. The literature on economic growth focusses on determinants of growth such as technological change, capital accumulation, energy, and the quantity and quality of labour supply but not on the importance of energy efficiency. This work investigates whether energy efficiency influences economic growth and to what extent.

Energy is a central input for most economic activities and two important trends that emphasise the importance of energy efficiency have been found in the academic literature.

First, energy use has decoupled from economic growth in recent decades, meaning that more GDP has been created per unit of energy. Energy productivity, which is defined as GDP per unit of energy used, has increased over time for many countries and is higher in resource scarce countries, as illustrated in Figure 1. Academic evidence confirms this trend of decoupling for the US (Ockwell, 2008) and Europe (Gales et al., 2007). Part of the underlying explanation lies in the movement away from energy-intensive industries towards the service sector but a further factor is the more efficient use of energy.

Figure 1. **Energy productivity increased over time and with levels of GDP per capita**



Note: *Each line becomes thicker over time; the data shown ranges from 1979 to 2010.*

Source: *Vivid Economics*

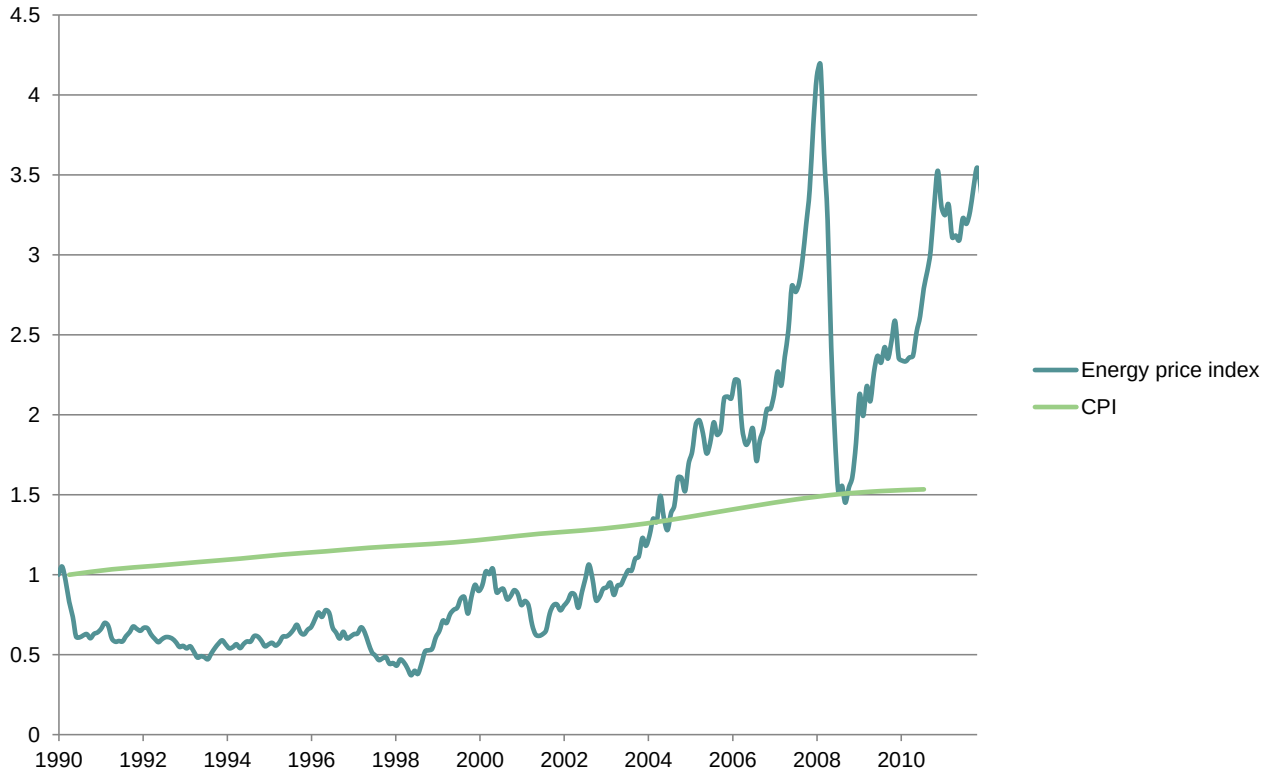
Second, energy prices have risen rapidly in the last decade and sharp increases have often been followed by recessions. Global energy prices have risen rapidly in the last decade as shown in Figure 2. Meanwhile, energy production, in particular oil production, has been steady or rising, showing that economies have grown while relying on energy as an input. This has led some economists to hypothesise that energy price shocks are one of the major causes of the contractions that occurred in the United States in the early 1980s (Killian, 2008) and in 2007-2008 (Hamilton, 2009). Killian (2008) surveys recent literature and finds that oil price shocks driven by shifts in expectations of future supply shortages have 'immediate and large effects on the US economy'.

The efficient use of energy can contribute to steadier and potentially higher economic growth by reducing the amount of energy required per unit of output and by reducing energy demand and, hence, prices.

In addition, in face of rising energy costs and increasing taxation of emissions, including emissions from energy generation, energy efficiency can provide industries and countries with a competitive advantage. As real energy prices have been rising over the last decade and energy is a significant factor of production, more energy efficient industries and countries have a competitive cost advantage (McKinsey, 2011). Some recent regional initiatives to reduce emissions have begun to price these emissions. Any reduction in energy used can contribute not only to lower levels of emissions from energy generation but also

to a reduction in the costs incurred by industries under tradable emissions schemes such as the EU ETS or in Australia.

Figure 2. **Global energy prices have risen faster than other prices over the last decade**



Note: *The global energy price index is calculated comprises of the prices of oil, gas and coal based on the World Bank. The CPI is a global average.*

Source: *Vivid Economics based on GEM Commodities World Bank energy price index*

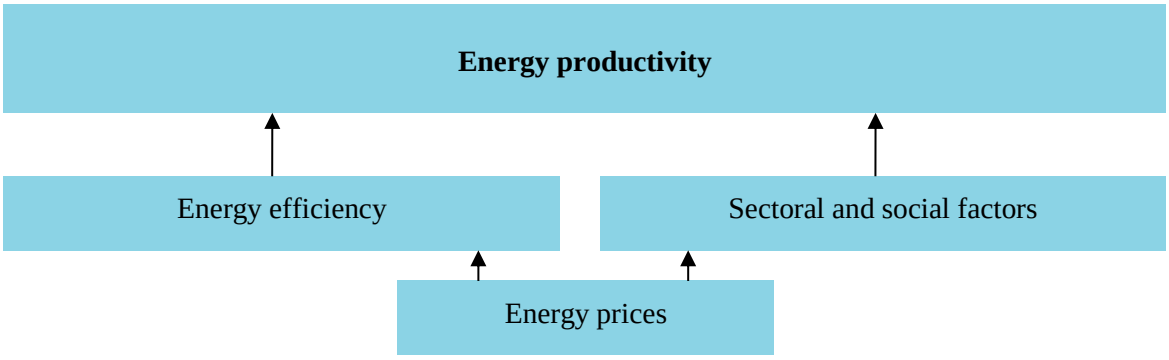
Energy efficiency measures might furthermore provide financial savings while being a cost-efficient way to reduce emissions. Energy efficiency measures, while involving costs themselves, reduce the costs of purchasing energy while also reducing emissions. According to one assessment, although there is not yet general consensus over figures of this type, energy efficiency measures are able to save, over a period of years, more than US$1.2 trillion at an investment cost of less than half of this, reducing by 23 per cent projected 2020 energy demand in the US alone (McKinsey, 2011).

1.1 Estimating energy efficiency

Two concepts that are central to this analysis are energy productivity and energy efficiency. Energy productivity is defined as GDP per unit of energy used and is a measure of the economic value associated with energy use. It is the inverse of energy intensity. Energy efficiency, on the other hand, measures the amount of energy used in the production of a specific service, such as a unit of residential lighting. Energy efficiency is one determinant of the overall energy productivity in an economy. The remaining determinants

are energy prices, which influence the allocation between energy and other production resources, the composition of GDP and social preferences as shown in Figure 3.

Figure 3. **Energy efficiency is a part of energy productivity**



Source: *Vivid Economics*

The analysis considers indirectly the effect of energy efficiency on economic growth. There exists no usable data on energy efficiency. The analysis considers energy productivity and its effect on economic growth. As energy efficiency is a component of energy productivity, the estimates do not show its effect on economic growth separately from other factors which underlie energy productivity. By including the share of services of GDP we account for some of the other variables affecting energy productivity.

Since energy efficiency has a positive effect on energy productivity, the results will be indicative of the direction and maximum size of the effects of energy efficiency measures on economic growth. Any improvement in energy efficiency implies that less energy has to be used per unit of output. Hence, the results obtained using energy productivity as a proxy provide the direction and magnitude of the effects of energy efficiency on economic growth.

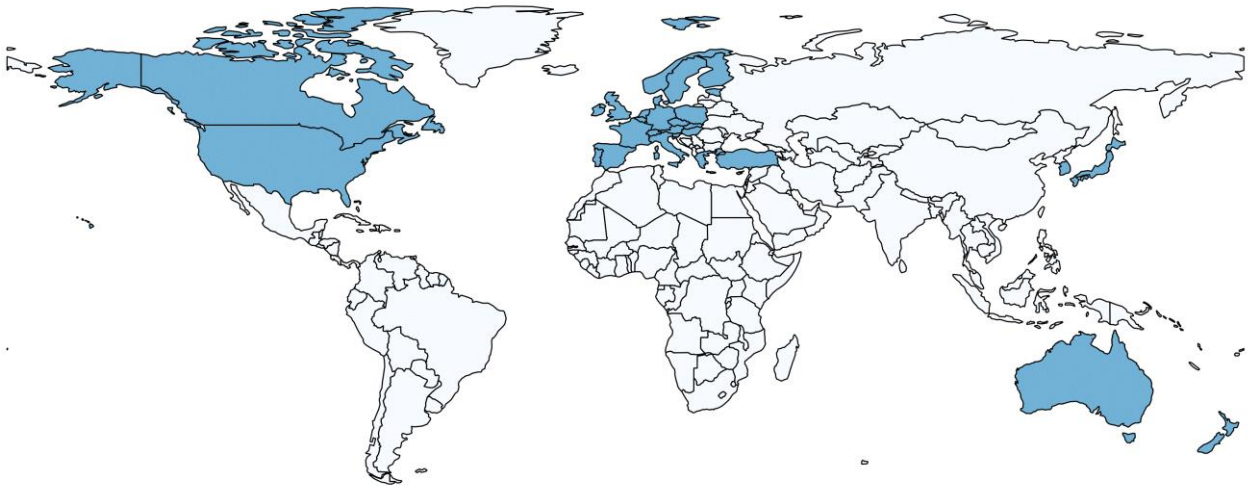
1.2 Methodology

The data set spans a wide range of countries over a long period of time which has the benefit of encompassing a considerable variation between countries as well as over time within countries. The data set allows the analysis of idiosyncratic effects, such as whether a country is an energy importer or exporter, an example of a factor which varies by country and over time. Furthermore, the analysis controls for the sectoral composition of the economy, both between countries as well as within a country over time, and thus accounts for the changing nature of energy use as economies mature.

Twenty eight diverse economies over a period of three decades are analysed to ensure that the obtained results are applicable to a wide range of developed countries. Each of the 28 countries highlighted in Figure 4 has undergone changes and transitions over the period. Major changes are, for example, the transition from communism to a market economy in the case of Eastern European countries or

the rapid industrialisation and subsequent switch to a growing service sector in countries like South Korea. The inclusion of a broad range of countries over a long period of time increases the robustness of results.

Figure 4. **Countries included in the energy efficiency study are all OECD members as only their energy data is available with good quality**



Note: *Comprehensive energy price data is only available for OECD countries.*

Source: *Vivid Economics*

The methodology allows causality to be established, that is whether energy efficiency gains are causing economic growth, and enables the identification of the direction and maximum size of the effect of energy efficiency on economic growth. Instrumental variable techniques are used to determine the effect of energy productivity gains on output. Output is measured as GDP per capita in US$2005 and adjusted for purchasing power parity (PPP). Energy price movements are used to help us obtain an estimate of the causal effect of energy efficiency on economic growth.[2] Furthermore, the ratio of the share of the service sector, which is often the most energy productive, to the share of industry, which is the least energy productive, is included to account for difference in countries' economies.

[2] Based on their found statistical relationship with energy productivity, real PPP adjusted retail energy price indices of oil, gas and electricity are used. Wholesale prices have been found to be a less significant predictor of energy productivity and are hence omitted.

2 Energy efficiency and economic growth

This report aims to identify and quantify the potential effect of energy efficiency on economic growth. The approximated level of energy efficiency and the per capita rate of economic growth are used in the analysis.

This report investigates the empirical effect of energy efficiency on economic growth without identifying the exact mechanism underlying it.

The estimates are based on historic evidence; any future gains in economic growth due to energy efficiency might be different. The analysis considers the causality between energy efficiency and economic growth over the last three decades. It may not offer a guide to the contribution of energy efficiency measures to economic growth in the future since the underlying factors of the relationship are open to change.

Analysis of the group of 28 countries considered as a whole will produce the most accurate estimate of the effects of energy efficiency, yet this estimate is not applicable to each country individually. The use of the whole group of 28 countries results in over 550 observations, which is a reasonable size for a data set. The obtained estimate shows the results for the group of countries. It is not representative of a single country.

2.1 Empirical results for the panel of countries

The analysis shows that improvements in energy efficiency have an effect on economic growth for the whole group of countries. There is statistical evidence that energy efficiency positively contributes to economic growth. A 1 per cent increase in the level of energy efficiency causes a 0.1 percentage point increase in the rate of economic growth in that year.

Table 1. **There is evidence that higher levels of energy efficiency positively affect economic growth**

Estimate	Significance level	Interpretation
0.10	**<1 per cent**	a 1 per cent increase in the level of energy efficiency causes a 0.1 percentage point increase in the growth rate of GDP per capita (for example from a growth rate of 2 per cent per annum to 2.1 per cent per annum)

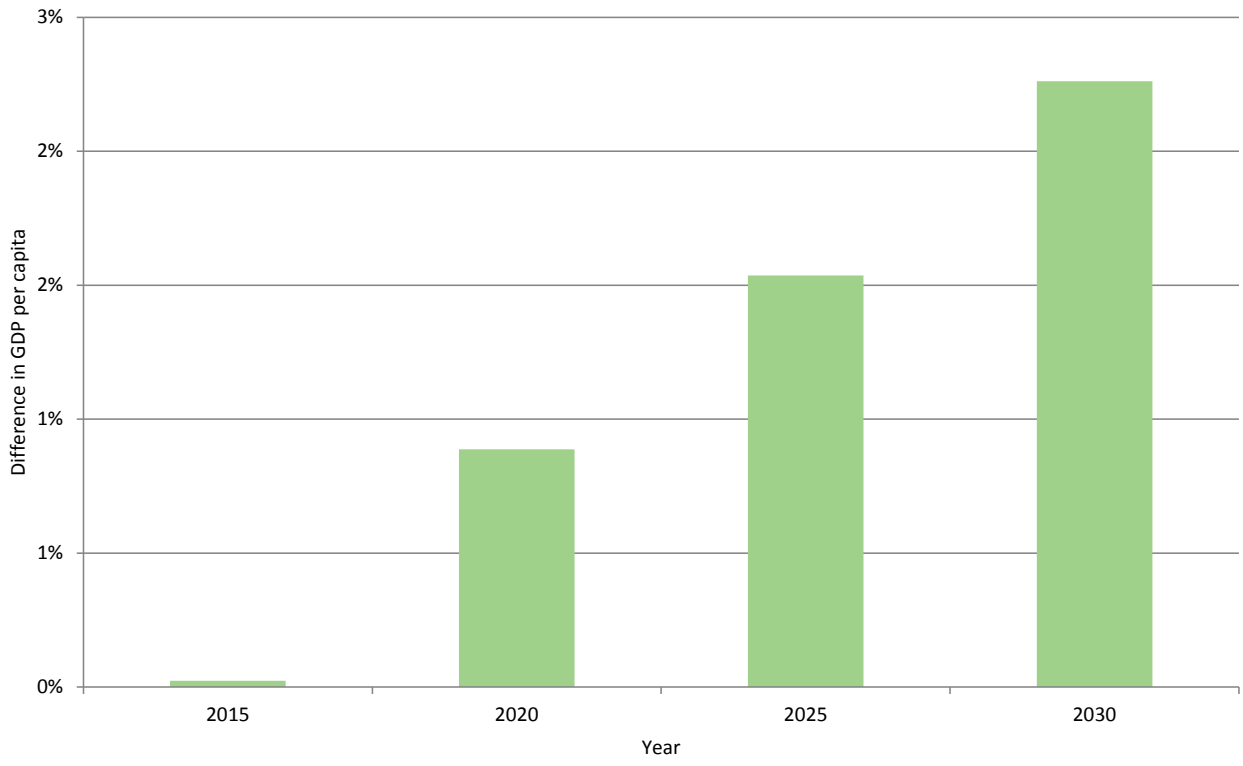
Note: *Significance level means the likelihood this estimate has been obtained by chance and that there is no relationship. A lower number implies a higher statistical significance of the estimate.*

Source: *Vivid Economics*

Assuming the average effect energy efficiency has on growth rates for most countries in the sample[3], if energy efficiency levels are increasing each year by 1 additional percentage point, their combined GDP would be 612 billion US$ larger in 2030 than currently projected, representing a 1.78 per cent increase. If energy efficiency grows at an additional percentage point from 2012 through to 2030, its level would reach 20 per cent above the projected baseline by 2030.

Taking the average energy efficiency effect across the panel of countries and applying it to Australia, if energy efficiency levels are increasing each year by 1 additional percentage point, GDP per capita would be 2.26 per cent higher in 2030 than currently projected and total real GDP gains of 25 billion AUS$[4] would be realised. If energy efficiency grows at an additional percentage point from 2012 through to 2030, its level would reach 20 per cent above the projected baseline by 2030. This additional efficiency would cause GDP per capita to be 2.26 per cent higher in 2030 than it would be otherwise, as shown in Figure 5.

Figure 5. **Higher energy efficiency levels contribute to growth and continue to do so in the long run**



Note: *This scenario assumes the OECD forecast for GDP per capita until 2030 and compares it with an additional one percentage point gain in energy efficiency levels per year and the effect on GDP per capita growth rates and levels.*

[3] Comparable 2030 GDP projections for non-OECD members (Bulgaria, Cyprus, Kazakhstan, Lithuania, Malta and Romania) are unavailable.

[4] Using a market exchange rate of 0.96 AUS$ per 1 US$.

Source: *Vivid Economics*

3 Policy implications

Rising energy prices provide an incentive to use existing energy sources more efficiently. Prices for gas, coal, oil and electricity have risen substantially over the last decades in real terms. Raising energy efficiency can result in more competitive industries and, as this analysis shows, has contributed to economic growth in the past.

To inform advice on energy efficiency policy, three pieces of evidence would have to be considered, each building on the preceding:

- *first*, how far energy and economic growth are interlinked;
- *second*, the effect energy efficiency has on economic growth; and
- *third*, the potential for energy efficiency measures.

For the *first piece of evidence*, previous academic evidence has established that energy and economic growth are deeply linked and that shocks to energy prices can contribute or even trigger economic downturns. The relationship between energy and economic growth has been extensively investigated. Energy is a key input in economic activity and energy and economic output are interlinked, although the exact causality is yet to be determined. In addition, changes in energy prices have a direct influence on economic output and growth.

This report provides initial estimates for the *second piece of evidence*, namely the effect energy efficiency has on economic growth. The analysis indicates that energy efficiency improvements have had a positive impact on economic growth over the last three decades.

One of the main factors influencing the magnitude of the beneficial effects of energy efficiency measures on growth is the potential of economically feasible, that is, cost-efficient, energy efficiency measures. Countries at the frontier of energy efficiency will have fewer opportunities for improvement than laggard countries. The frontier itself is country specific because of factors such as the prevalence of energy-intensive industries like mining and other factors such as local energy prices.

To fully evaluate the impact of energy efficiency measures, the potential for energy efficiency gains needs to be taken into account, which is the *third piece of evidence*. Past contributions of energy efficiency to economic growth might reflect great potential for improvement. As economies become more efficient over time, economically feasible energy efficiency gains might decline.

Recent academic studies have estimated the energy efficiency potential of different countries. Filippini & Hunt (2011), Wang (2011), Wei, Ni, & Shen (2009) and Stern (2012) use stochastic functions to model the energy efficiency potential. Stern (2012) attempts to estimate energy efficiency using a production frontier technique and produces estimates of the difference between current energy efficiency levels in 85 countries and the world's best practice level of energy efficiency.

Future analysis can shed light on the relationship between energy efficiency and growth and the energy efficiency potential for individual countries. Individual country models can be tailored more

closely to the economic situation in the country and can provide more detailed estimates of the energy efficiency potential and its effect on economic growth.

This report provides evidence that energy efficiency measures are not detrimental to growth but can, in fact, contribute to it. It provides an initial evidence base for the missing link between the already investigated relationship between energy and economic growth and recent estimates of the potential for energy savings. It offers a qualitative estimate of the potential for energy efficiency measures to contribute to economic growth.

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