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Conditional convergence in Australia's energy consumption at the sector level☆

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ABSTRACT

We examine the convergence of energy consumption per capita at the sector level in Australia over the period 1973–74 to 2013–14. To do so, we employ recently developed LM and RALS-LM unit root tests that accommodate up to two endogenously determined structural breaks. We find support for energy consumption per capita convergence for six of seven sectors in Australia.

1. Introduction

A small literature has evolved over the last few years that has applied unit root tests to test for stochastic conditional convergence in energy consumption. Most of the existing studies have applied unit root tests to test for stochastic conditional energy convergence among groups of countries (see Anorou and DiPietro, 2014; Meng et al., 2013; Mishra and Smyth, 2014). These studies have mostly found evidence of stochastic conditional convergence in energy consumption. Payne et al. (2017) applies unit root tests to test for stochastic conditional energy convergence between states in the U.S., also finding evidence of convergence in energy consumption.

Recently, there have been several calls for studies to test for stochastic conditional convergence at the sector level for different countries. For example, Meng et al. (2013, p. 545), who apply LM tests based on the residual augmented least squares (RALS) regression proposed by Lee et al. (2012) and Meng et al. (2014) to test for stochastic conditional convergence in energy consumption among OECD countries, suggest: "Future research can extend the methodological approach taken in this study [to] …. sector analysis of energy use convergence within a specific country as well as across countries". Similarly, Mishra and Smyth (2014, p. 184) propose: "Future research could consider convergence in disaggregated energy across sectors". Finally, in a recent review of econometrics developments in energy economics research, Smyth and Narayan (2015, p. 353) write: "Future research could examine convergence in energy consumption at the sector level within specific countries".

Studies at the sector level are needed because findings for stochastic conditional convergence in energy consumption at the national, or state, level potentially mask important differences between sectors. Studies that cover a range of sectors, such as commercial, manufacturing, residential and transport, are needed to ascertain whether existing findings are applicable at a more disaggregated level within specific countries. There is a clear analogy here with studies that have tested for Granger causality between energy consumption and economic growth and studies that have examined whether there is a unit root in energy consumption. Studies in these areas have shown that findings when energy consumption is measured at the national level are not necessarily apposite when energy consumption is measured at the sector level and that findings sometimes vary across sectors (Smyth and Narayan, 2015).

Yet, we know very little about stochastic conditional convergence in energy consumption at the sector level. To this point, the only existing study, of which we are aware, is Lean et al. (2016), who test for stochastic conditional convergence in aggregate and disaggregate petroleum consumption at the sector level for the U.S. The findings in Lean et al. (2016) were not conclusive, with evidence of stochastic conditional convergence for just over half of the 45 series examined. Further research is needed to disentangle these mixed findings. In addition, the

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U.S. has introduced a number of federal and state-level policies to reduce fossil fuel consumption since the oil crises that occurred in the 1970s (see Payne et al., 2017 for a discussion). The findings in Lean et al. (2016) for the U.S. at the sector level may reflect these policies and, as such, not be representative of other countries that have not introduced such policies or for which the timing of the introduction of such policies have differed.

We contribute to the literature by testing for stochastic conditional convergence in energy consumption at the sector level for Australia. Australia is an interesting country in which to situate such a study. While it has traditionally been one of the highest consumers of energy on a per capita basis in the world (Falk and Settle, 2011), Australia's energy consumption has been falling since 2011–12 and in 2013–14 was similar to 2009–10 levels (Department of Industry and Science, 2015b).

Most of Australia's energy consumption is from oil, including crude oil, liquefied petroleum gas and refined products, coal and natural gas. In 2013–14 oil constituted 38.4% of Australia's energy consumption, coal constituted 31.7% of Australia's energy consumption and natural gas constituted 24% of Australia's energy consumption. Meanwhile, renewables represented just 5.9% of Australia's energy consumption (Department of Industry and Science, 2015b).

Table 1 shows the break down in energy consumption across sectors since 1980–81. Since 1980–81, electricity supply, manufacturing and transport have been responsible for the lion's share of final energy demand in Australia. In 2013–14 electricity supply, manufacturing and transport together accounted for just under three quarters (74.61%) of final energy demand. In 2013–14, mining, residential, commercial and other each accounted for less than 10% of final energy demand. Over time, there has been a decline in the final energy demand share of manufacturing from 30.07% in 1980–81 to 20.34% in 2013–14 and an increase in mining's share from 2.26% in 1980–81 to 9.11% in 2013–14. The drop in Australia's energy consumption in manufacturing over time is largely attributable to decline of the automobile sector in Australia (Productivity Commission, 2014).

Australia's climate change policy has two platforms. The first is “Direct Action”, which entails the Government operating a reverse auction process to allocate AUD 2.5 billion to fund emission reduction projects. The second is a 20% renewable energy target, which requires electricity retailers to fund small-scale solar PV systems and increase the proportion of large-scale renewables in the overall electricity mix (see Nelson, 2015 for more details). At the United Nations Framework Convention on Climate Change Conference of the Parties (COP) in Paris, Australia stated that it will reduce greenhouse gas emissions by 26–28% by 2030 compared to 2005 levels. In the commentary since, it is generally thought that “achieving these emission reductions will be challenging under current policy settings” (Nelson et al., 2015).

The results from this study are important in this context because knowledge of the existence, or otherwise, of stochastic conditional convergence in energy consumption is useful in ascertaining whether policies designed to reduce the intensity of energy consumption are proving effective. With stochastic conditional convergence in energy consumption, as with pollution emissions, the underpinning premise is that there is downward convergence. Jakob et al. (2012, p. 101) note: “For industrialized countries, we find that economic growth is partially decoupled from energy consumption and that above average rates of economic growth were accompanied by larger improvements in energy efficiency”. This has resulted in a reduction in per capita energy use among high-income countries. Meng et al. (2013, p. 544) note:

> “the reduction in the disparities in per capita energy use among OECD countries can be attributed to the increase in energy efficiency, the decrease in energy intensity and greater public awareness of global energy issues and desire to mitigate carbon dioxide emissions which contributes to convergence of per capita energy usage among these countries”.

Maza and Villaverde (2008) point put that the reduction in the disparities in per capita energy use in the OECD reflects government policies to reduce energy intensity, promote energy efficiency and increase public awareness of climate change. In other words, government policies in high-energy intensity countries have been designed to encourage convergence, such that their success is linked to convergence. Specifically, Maza and Villaverde (2008) note that convergence in per capita energy use is consistent with the adoption, and promotion, of demand and supply side policies to curtail consumption. On the demand side, Maza and Villaverde (2008) suggest that such policies include (a) making consumers pay the real price of energy consumed; (b) subsidizing use of energy-efficient technologies; and (c) launching promotion campaigns to change energy consumption habits. On the supply side, policies include supporting codes of conduct, such as voluntary agreements with manufacturers establishing minimum efficiency levels and energy management guidelines.

Another reason for focusing on convergence at the sector level is that one would expect the applicability of such policies to vary across sectors. For example, convergence in electricity supply might be aided through policies such as the Renewable energy target, requiring retail electricity suppliers to increase the amount of renewable energy in the fuel mix. Convergence in the manufacturing or mining sectors may be aided through the forced closures of inefficient facilities, assignment of energy saving targets or subsidies to introduce energy efficient technologies. Convergence in energy consumption in transportation could be aided through introduction of fuel economy standards and labelling, vehicle and fuel taxation, subsidies for energy efficient and electric vehicles and making public transport more accessible and affordable (Lo, 2014). In addition, even where specific policies, such as campaigns to change consumption habits, have application across multiple sectors, the specific manner in which such policies are framed will likely differ.

Within a single country, such as Australia, if there is stochastic conditional convergence in energy consumption at the sector level, this would be consistent with government policies targeted at decreasing energy intensity, enhancing energy efficiency and reducing carbon emissions from fossil fuels in the high energy intensity sectors, such as electricity supply, manufacturing and transportation, being effective in contributing to convergence (see Payne et al., 2017). These policies include improved efficiency of air conditioning, electronics and refrigeration, energy efficiency requirements in the Building Code and subsidies for renewable energy use, such as rooftop solar panels (Bureau of Resource and Energy Economics, 2014).

However, if we fail to find stochastic conditional convergence, then we cannot conclude that existing policies have contributed to convergence and alternative policies mooted in Australia to reduce energy consumption may need to be considered. These include a carbon tax, specific performance standards establishing separate greenhouse gas limits for coal and gas generators and use of alternative energy sources, such as uranium (see Climate Institute, 2014; Nelson, 2015).

From a methodological perspective, we follow Meng et al. (2013) and Payne et al. (2017) and employ LM and RALS-LM unit root tests

Table 1
Percentage breakdown of final energy demand by each sector.
Source: Department of Industry and Science (2015a), Table E and authors' calculations.

Sector	1980–81	1990–91	2000–01	2010–11	2013–14
Electricity supply	24.73	26.96	30.09	28.63	27.02
Transport	26.55	25.39	24.92	25.81	27.25
Manufacturing	30.07	27.19	23.71	22.68	20.34
Mining	2.26	4.17	5.07	6.86	9.11
Residential	8.35	8.3	7.94	7.69	7.7
Commercial	3.39	3.97	4.46	5.09	5.42
Other	4.65	4.02	3.82	3.25	3.16