Differential Electricity Pricing and Energy Efficiency in South Africa

Marcel Kohler (Academic Leader, School of Accounting, Economics and Finance, UKZN)
kohler@ukzn.ac.za
Harry Plumstead (Research Assistant, UKZN)

Abstract

If South Africa is to curb CO_2 emissions from electricity generation it would be in the country's best interests to encourage change in sectoral electricity consumption behaviour in response to price changes. This change should include both energy efficiency improvements and energy technology changes in economic sub sectors. Research by Blignaut and de Wet (2001) and Inglesi (2010 & 2011) suggests that the relation between electricity consumption and electricity prices differ by SA economic sector. This finding is particularly relevant if the high energy intensity of the SA economy is due to its structure rather than the energy efficiency of its economic sub-sectors. In the absence of clearly informed energy policy and a differentiated energy pricing regime, efforts by policy makers to bring about structural change in the economy could adversely affect the country's energy and environmental targets.

This paper attempts to model the impact of a differential electricity pricing policy on energy efficiency in SA. This policy is informed by the decision of the National Development and Reform Commission (NDRC) of China which in 2004 established a policy permitting differential electricity pricing for high energy-consuming industries in which electricity prices are based on the energy intensity level of each enterprise in an effort to encourage structural reform.

In order to estimate the effects of differential electricity pricing practices on energy consumption we employ a standard theoretical model informed by the energy economics literature:

$LnCons_{it} = \beta_{0,I} + \beta_{1,i} LnPrice_{it} + \beta_{2,i} LnOutput_{it}$ where *cons* is the electricity consumption, *price* is the price of electricity and *output* is the total output of the sector *i* at time *t.*

Introduction

In 2010, South Africa committed itself to reducing its greenhouse gas emissions by 34% by 2020 under the United Nations Framework Convention on Climate Change (UNFCCC) (Winkler et al, 2010). Developing countries, such as South Africa, tend to have a comparative advantage in resource based industries which are generally energy-intensive and pollution-intensive in nature. The government's efforts to provide affordable electricity to previously overlooked, rural areas has also contributed to the rapid increase of energy demand since 2002. According to Banks and Schaffler (2006), the South African economy will require triple the amount of energy by 2050 if it grows at growth rates forecasted by the NER. Given that electricity generation is the source of over 60% of annual greenhouse gas emissions, it is necessary for South Africa to improve its energy efficiency if it is to avoid emissions-induced environmental damage as its economy grows (Blignaut, 2011).

The industrial sector consumes, by far, the largest proportion of South Africa's electricity output. Industry was also found by Inglesi (2011) to be the only sector in which output is responsive to changes in the electricity price, suggesting that it be the focus of policy designed to reduce electricity consumption and increase energy efficiency in South Africa. Reductions in energy consumption, brought about by closure of inefficient firms and investment in less energy-intensive production processes, could be achieved by raising the price of electricity for targeted sectors.

In the short run, an electricity price increase would constrict growth by raising input costs in targeted industries. If, however, price increases are diversified amongst high-energy consuming industries and higher income regions then the associated negative impacts could be minimised. Government could pursue a policy of differential electricity pricing, similar to that which the Chinese government implemented in 2004, targeting energy intensive industries to encourage greater energy efficiency and CO_2 emissions reductions.

China’s Differential Pricing Policy

In its present form, without a competitive market price, China’s power industry is struggling to balance supply and demand. China’s demand for energy has outpaced growth in installed capacity, leading to a supply deficit. The resulting power shortages have been affecting economic welfare and the environment, prompting the government to undertake a number of energy policy reforms since 1985.

The governments influence over the electricity price enables it to modulate inflation and volatility that could damage welfare and economic growth. This pricing mechanism does, however, have its drawbacks. Coal is used in approximately 80% of China’s thermal energy production (Edwards, 2012). When coal prices increase, energy utilities’ costs rise sharply, compressing profit margins. The energy producers’ inability to raise electricity prices can lead to large losses in the industry and a lack of funds with which to invest in new capacity. In 2010, the State Electricity Regulation Commission (SERC) reported combined deficits for China’s five largest thermal power producers of 6.23 billion dollars from 2008-2010.

In an attempt to reduce energy consumption per unit of GDP by 20% between 2005 and 2010 and abate pressure on generation capacity, the Chinese government instituted special energy pricing policies (Zhou, 2010). The Top-1000 program focused on the 1000 largest companies in China, which collectively consume approximately one third of the nation’s energy supply (Lewis, 2011). A differentiated electricity pricing policy (DEPP), which aimed to reduce the growing pressure on installed capacity, was implemented in June 2004. Energy intensive industries that did not meet specific efficiency and environmental targets were taxed under the DEPP by being forced to pay a higher electricity price (Edwards, 2012). Initially the ferroalloy, aluminum, caustic soda, cement, steel, and calcium carbide industries were subject to the pricing policy, with phosphorus and zinc smelting being included later in September 2006. Firms in these industries were divided into four categories, namely encouraged, permitted, restricted and eliminated, with the latter two (low output, low efficiency firms) paying a surcharge on the basic electricity price (Edwards, 2012). The former two categories received an adjustment to the provincial wholesale electricity price. Surcharges for restricted and eliminated enterprises were 5 fen and 20 fen per kwh respectively, approximately 10%-20% of the basic price (Price et al, 2010). The objective was to drive inefficient firms out of the market or to force innovation or investment in less energy-intensive production methods.

The new pricing policy garnered little support from municipalities, and a number of problems were encountered with local adoption. The policies' detrimental impact on local economic growth, coupled with fierce local competition, made localities reluctant to implement the policy and led them to institute their own preferential pricing policies, which lowered energy costs for more efficient industries. In 2006, however, the National Development and Reform Commission (NDRC) eliminated all preferential pricing policies, believing that they undermined the DEPP by benefiting industries that were still relatively energy intensive. Surcharges for the restricted and eliminated categories were not always high enough to drive inefficient firms out of the industry or force innovation in production processes. These surcharges were subsequently increased by the NDRC in September 2006 (Edwards, 2012).

Another problem experienced early on was a lack of transparency with regards to the beneficiaries of the surcharge revenues. To address this problem, in 2006 it was decided that the Ministry of finance would receive these funds. In 2007, however, the recipient of the DEPP revenue was changed to the province-level Department of finance to help improve compliance at local government level (Edwards, 2012).

Despite the aforementioned problems with implementation, by 2006, approximately 1280 firms in the targeted categories had already been forced out of the market, or had invested in or converted to more energy efficient production techniques (Price et al, 2010). The overall reduction in energy intensity between 2006 and 2010 was likely to be somewhere around 19.1%, not far from the ambitious original goal of 20% (Lewis, 2011).

Although China has made progress in reducing energy intensity through energy reforms, electricity supply is still forecasted to lag significantly behind demand in the coming decades. Li (2008) argues that China will experience an 'insurmountable energy crisis' that will eventually end Chinese economic growth. He maintains that even with optimistic assumptions regarding capacity expansion China's economy will fall into negative growth territory by 2050.

So, it is debatable whether China's demand-side energy pricing policy reforms will be effective enough to allow for sustainable growth in the long term. Edwards (2012) argues that China should instead focus on better supply-side regulation to ensure that sufficient capacity is available, and stabilizing the price of electricity to preserve economic growth. He also suggests the introduction of alternative demand side policies, such as time of use, which would punish inefficient users.

The South African Electricity Sector

The availability of resources and the reliability of factor inputs are important determinants of productivity. It is crucial for an economy to be able to generate and distribute a sufficient supply of electricity if sustainable economic growth is to be achieved. At present, there is no feasible method to store electrical power on a country-wide scale. The installed capacity must, therefore, be able to generate enough electricity to meet peak demand (Edwards, 2012). Growth in capacity to generate power must keep up with growth in demand from consumers in order to avoid economically damaging blackouts or brownouts.

Power shortages hinder growth not only by decreasing productivity, but by forcing firms to re-optimize among factors by using more material, and fewer energy inputs (Fisher-Vanden et al, 2013). Firms will tend to produce fewer (and possibly import more) of the inputs required in the production of their final output. If blackouts become too frequent, firms may even resort to generating their own energy inputs. In a study of China's electricity supply shortages of the early 2000s, Fisher-Vanden et al (2013) found that the overall effect of the power shortages was to increase production costs, finding no evidence of an increase in self-generation.

Electricity supply can be divided into three components, namely generation, transmission (high-voltage) and distribution (low voltage) (Lockwood, 1992). In certain countries, such as the UK, all three components of electricity supply are managed by separate companies. Eskom, South

Africa's power utility, undertakes all three supply activities, and takes the form of a state-regulated monopoly. Eskom's lack of competition and access to government funds has provided little incentive to cost cut and operate efficiently. Government will be tempted to keep electricity prices artificially low, creating a situation where the utility is unable to fund maintenance and investment out of profits (Newbery and Ebehard, 2008).

The price consumers pay for electricity in South Africa is determined by government, and not demand-supply forces in the market. The lack of an equilibrating price mechanism can lead to temporary demand-supply imbalances, especially if government is slow to react to market signals. In a situation where the price of electricity is driven by supply and demand, a high price would signal excess demand and would soon drive more investment into the industry. High electricity prices also encourage innovation in alternative methods of power generation, as well as greater efficiency in consumption and in production processes in which electricity is a key input (Edwards, 2011). Without a market-determined electricity price it is up to regulators to forecast the future energy needs of the economy and make the appropriate capacity investments.

The price of electricity in South Africa lies below the cost to generate new power, or long-run marginal cost (Newbery and Eberhard, 2008). According to Newbery and Eberhard (2008), this has lead to excessive electricity consumption and shortages of investment in supply. They argue that electricity prices need to rise significantly to provide a sufficient rate of return and pay for the cost of new power. Energy-intensive industries have, in some cases, been supplied electricity at prices far below the residential tariffs, further encouraging inefficient energy consumption. Alusaf, South Africa's primary aluminium producer, has benefited from a 25 year pricing contract with Eskom, which ensures a constant supply of electricity at a price linked to the London Metal Exchange aluminium price. Government has been reluctant to raise tariffs for large industrial players, fearing a drop in international competitiveness and the resulting impact on the balance of payments.

The external cost in the energy industry is the difference between the cost to the industry and the cost to society that are incurred in the process of generating and supplying electricity. A negative production externality, such as the emission of GHG by coal-fired power stations, will lead to under-pricing of energy if external costs are not taken into account (Black et al, 2012). South Africa's generous endowment of coal resources, and heavily regulated energy industry have also contributed to a low real electricity price. Raising electricity tariffs to a more efficient level would also relieve some of the stress on supply capacity and provide much needed cash flow that could be channeled into investment.

Within industry, each sector will react differently to an increase in electricity prices. Sectors in which energy costs make up a negligible portion of total costs will probably exhibit low or insignificant price elasticities. For example, electricity costs contribute about 0.081% of total costs in the newspaper, journals and periodicals sector, indicating that a change in electricity prices will have little effect on profit margins. On the other hand, tariff increases would have a much larger effect on profits in the plastics sector, where electricity costs make up roughly 14% of total costs (Inglesi, 2011). Energy-intensive industries with relatively high electricity cost to total cost ratios could be subjected to tariff surcharges with the aim of reducing emissions.

Of the industrial sectors, mining and quarrying is the most power hungry, consuming approximately 14% of total electricity usage in 2006 (Inglesi, 2011). Roughly 3.7% of the sector's total costs are in the form of electricity tariffs, compared to an average of 1.02% across all sectors. The high relative importance of energy inputs in mining and quarrying, coupled with its comparatively high energy consumption make it an ideal target for a differential pricing policy aiming to reduce consumption and curb emissions. Other possible targets include the basic iron and steel and non-ferrous metal sectors. Sectors whose energy inputs can be readily substituted for labour inputs would tend to have higher and more significant price elasticities. A price increase would, in this case, reduce energy consumption and emissions without significantly affecting output in the process.

Table 1: Carbon intensity measures for aggregate South African sectors, 2005

	Carbon intensity (tons CO_2 per R1000 gross output)			Share of national total (%)		Employ-ment multiplier **
	Total	Direct*	Indirect	Gross output	Employ-ment	
All products	0.260	0.088	0.172	100.0	100.0	7.2
Agriculture	0.146	0.062	0.084	2.6	9.4	16.6
Coal	0.140	0.071	0.069	1.1	0.4	4.1
Natural gas	0.335	0.253	0.083	0.0	0.0	5.3
Crude oil	-	-	-	0.0	0.0	0.0
Other mining	0.292	0.221	0.071	4.6	3.3	4.9
Processed foods	0.186	0.066	0.120	5.5	2.0	8.1
Textiles & clothing	0.247	0.107	0.140	1.3	1.8	11.1
Wood & paper products	0.447	0.270	0.177	2.6	1.4	7.4
Petroleum	1.356	0.039	1.318	2.5	0.1	1.8
Chemicals	0.350	0.184	0.165	5.2	1.0	5.0
Non-metallic minerals	0.477	0.324	0.153	1.0	0.8	7.0
Metal products	0.430	0.257	0.173	4.7	1.9	5.4
Machinery	0.181	0.027	0.154	2.6	1.4	5.6
Vehicles	0.175	0.023	0.152	4.6	1.2	5.5
Other manufactures	0.150	0.028	0.122	1.2	1.2	8.0
Electricity & gas	3.143	0.295	2.848	1.7	0.3	3.2
Water distribution	0.537	0.486	0.052	0.6	0.1	3.7
Construction	0.202	0.027	0.175	3.7	6.0	11.3
Trade & catering	0.133	0.040	0.094	9.8	21.7	11.3
Transport & comm.	0.167	0.108	0.060	9.1	4.1	5.1
Financial services	0.024	0.006	0.018	7.0	2.9	3.4
Business services	0.159	0.084	0.075	9.0	11.7	8.0
Government	0.077	0.022	0.055	10.2	12.8	7.1
Other services	0.105	0.027	0.078	9.4	14.5	8.7

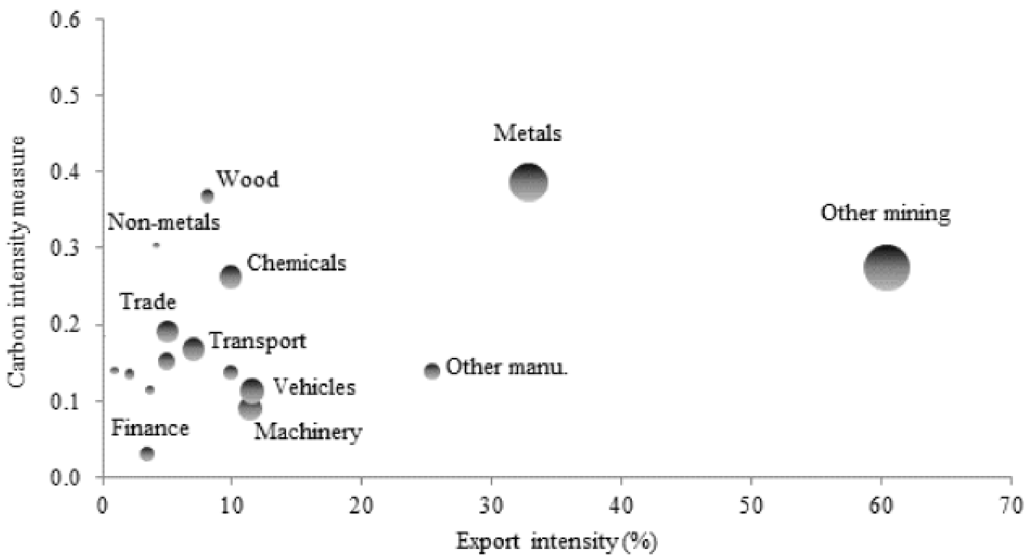
Source: Ardnt et al, 2011

Carbon intensity measures for South African sectors are presented in Table 1. Electricity and gas is by far the dirtiest industry primarily due to the high CO_2 content of its coal fuel inputs. Its total carbon intensity of 3.143 tons of CO_2 per R1000 of gross output (approximately 12 times that of the average for all sectors) highlights the importance of electricity generation and consumption to environmental policy.

Of the industrial sectors, Ardnt et al (2011) found non-metallic minerals and wood and paper products to be the most carbon intensive sectors. If substantial reductions in carbon emissions are to be made, however, industries must be targeted not only based on their carbon intensity, but also their relative size. Table 1 shows that non-metallic minerals and wood and paper products contribute only 1% and 2.6% of GDP respectively. Chemicals and metal products are dirty industries that comprise a relatively large share of GDP.

Raising tariffs for dirty and energy-intensive industries could adversely affect exports and the balance of payments in the short run. Table 2 compares the carbon and export intensities of various economic South African product sectors.

Figure 1: Carbon and export intensities for aggregate SA products, 2005



Source: Arndt et al (2011)

Figure 1 shows that the carbon intensity measures of South Africa's exports exceed, on average, that of other components of GDP. From the size of the sector markers, which reflect the contribution of the corresponding sector to total export earnings, it is clear that a number of South Africa's most carbon intensive industries (eg. Metals and other mining) are highly important to the BOP. Rising labour costs in these industries may make it difficult for regulators to increase their energy costs without compressing their profit margins to levels at which their international competitiveness is significantly reduced. However, due to the historically low, decreasing real price of electricity in South Africa, tariff raises may be seen as immaterial increases in costs in certain sectors. All South African economic sectors, barring industry, have exhibited a lack of price sensitivity, which has created an uncertain environment for policymakers. It is possible, however, that as real prices rise to higher levels the price elasticities of these sectors will become significant, and pricing policies more effective (Inglesi, 2011).

Methodology and Data

The methodology follows that used by Inglesi (2011), and attempts to model the potential effects of a differentiated energy pricing policy on energy consumption in the South African economy. Specifically, this paper undertakes to determine the effects of changes in energy prices and industrial output on electricity consumption. Electricity consumption is, thus, assumed to be a function of changes in electricity prices and output, with all variables in their natural log forms. Data from xxxxx was first regressed in a pooled effects ordinary least squares model to establish the responsiveness of electricity consumption to changes in the electricity price and aggregate industrial output. A Fixed effects analysis was then conducted to determine sector-specific effects and account for cross-sectional dynamics.

The pooled effects regression provides a joint estimation of the model:

$$LnCons_{it} = \beta_{0,I} + \beta_{1,i} \; LnPrice_{it} + \beta_{2,i} \, LnOutput_{it}$$

Where *cons* is the electricity consumption, *price* is the price of electricity and *output* is the total output of the sector *i* at time *t.*

Although useful to establish aggregate parameters, the pooled effects model does not account for any cross-sectional heterogeneity among sectors and increases the degrees of freedom, which lowers the standard errors of the estimators. A fixed effects regression is then conducted in order to account for cross-sectional dynamics.

Results

The results of the simple aggregate regression are similar to those obtained by Inglesi (2011). Energy consumption for the period 1993 to 2007 was, as expected, positively related to industrial output. Electricity consumption was found to be output/income elastic, with a 1% increase in industrial output, ceterus paribus, leading to a 1.13% increase in energy consumption. The results indicate that electricity consumption was price inelastic and negatively related to the electricity price over the period, where a 1% increase in price would lead to a 0.6% decrease in electricity consumption.

The coefficients of industrial output and electricity prices are both significant in the pooled effects regression results. The significant negative coefficient of the electricity price variable suggests that a differential pricing policy would be effective in curbing electricity demand if the industrial sector is targeted.

A fixed effects model was then used to control for the effects of the different sectors that comprise total industry. When data from 2003-2007 is regressed in a fixed effects model both coefficients become insignificant. As was the case in Inglesi (2011), cross-section heterogeneity might be causing the coefficients to become insignificant as the fixed effects model is allowing for sectoral differences in the data.