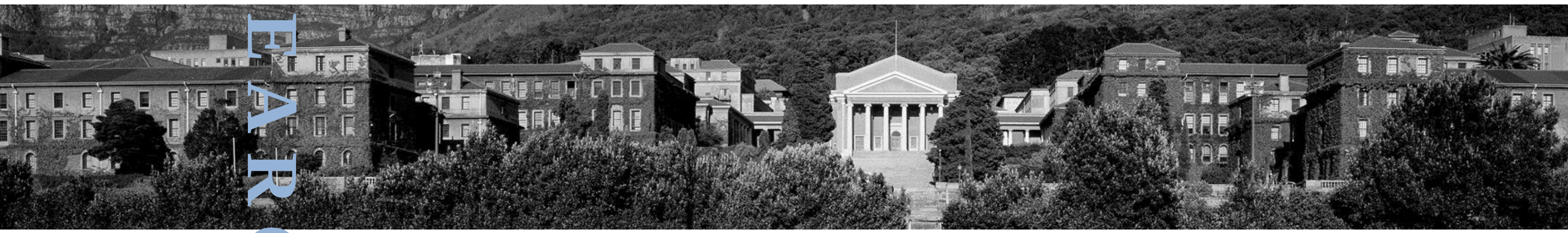
RESEARCH REPORT SERIES

ENERGY RESEARCH CENTRE
University of Cape Town



Economic benefits of extended producer responsibility initiatives in South Africa: The case of waste tyres[1]

FAAIQA HARTLEY[2], TARA CAETANO[3] AND REZA C. DANIELS[4]

November 2016

Key points

- This paper aims to expand on the initial analysis of a simple supply shock in Hartley, Caetano and Daniels (2016), to catalytic impacts from expanding the recovery and recycling industries that aren't seen in a simple supply shock.
- South Africa's social accounting matrix (SAM) is extended to display the waste tyre recycling industry.
- The results show that extended producer responsibility initiatives for waste tyres will lead to positive economic benefits, and up to 1 448 full-time equivalent (FTE) net new jobs that favour lower skilled people.
- It is likely that this paper underestimates the positive benefit to the economy from the internalisation of waste tyre externalities, since environmental benefits are neither quantified nor included in this analysis.
- The impacts could be larger if the capital accumulation between periods was accounted for by a dynamic analysis, rather than the static analysis used in this paper.
- These results suggest that extended producer responsibility initiatives that directly subsidise waste beneficiation activities and build recycling industries have significant potential for positive economic impacts in addition to environmental benefits.

[1] Funding for this paper is gratefully acknowledged from the Recycling and Economic Development Initiative of South Africa (REDISA). All views expressed, errors and omissions are the responsibility of the authors alone.

[2] Energy Research Centre, University of Cape Town: faaiqa.hartley@uct.ac.za

[3] Energy Research Centre, University of Cape Town: tara.caetano@uct.ac.za

[4] School of Economics, University of Cape Town. Corresponding author: reza.daniels@uct.ac.za

Suggested citation for this paper:

Hartley, F., Caetano, T. and Daniels R.C. 2016. *Economic benefits of extended producer responsibility initiatives in South Africa: The case of tyres*. Energy Research Centre. University of Cape Town. November 2016.

Energy Research Centre
University of Cape Town
Private Bag X3
Rondebosch 7701
South Africa

Tel: +27 (0)21 650 2521
Fax: +27 (0)21 650 2830
Email: erc@erc.uct.ac.za
Website: www.erc.uct.ac.za

Contents

1. Introduction

The National Waste R&D and Innovation Roadmap for South Africa (DST, 2014) outlines potential economic benefits of moving up the waste management hierarchy. By moving up the waste hierarchy towards reuse, recycling and recovery South Africa would not only contribute to the principles of a ‘green economy’, but also benefit from the development impacts of introducing the value of resources that are currently lost to the South African economy through waste disposal.

Since Novmeber 2012, through the Recycling and Economic Development Initiative of South Africa (REDISA) and the Integrated Industry Waste Tyre Management Plan (IIWTMP), approximately 170 000 tonnes of waste tyres have been recycled by October 2016. A number of jobs have been created ranging from unskilled workers that are employed as waste collectors to transporters, waste tyre depot owners and employees, waste to energy firms, pyrolysis producers and crumbing operation positions created or enabled by REDISA to fulfil their management and coordination responsibilities.

This paper aims to expand on an initial analysis of the potential economic impacts of recycled waste streams in South Africa (Hartley, Caetano and Daniels, 2016) to include a waste tyre recycling industry in the Social Accounting Matrix (SAM) of the computable general equilibrium (CGE) model for South Africa. The motivation for this is to capture the catalytic impacts from expanding the recovery and recycling industries that aren’t seen in a simple supply shock. Interpreting the model outcomes judiciously is a key factor in any CGE modelling exercise, and we encourage readers to note that CGE models are best utilised to understand the economy-wide interactions. Therefore, it's important to note the linkages between the new sector and other sectors/agents in the model and not necessarily the level of changes to GDP for instance. The CGE is not a predictive model, but is powerful when used as a simulation tool. The overall take-homes from this report are that there are significant net new employment opportunities, especially for low-skilled workers, and that introducing a waste tyre beneficiation industry would have a positive impact on the economy.

2. Waste Tyre Recycling Industry in South Africa

Waste tyres, which can include synthetic or natural rubber tyres, can be used in three main recycling industries, namely waste to energy, crumbing and Kraftek (craft-based uses of waste tyres). Waste to energy involves the conversion of shredded tyre waste into either electricity or fuel substitutes for coal. There are three technology options for waste to energy conversion. These include gasification, pyrolysis and incineration. In the process of gasification and pyrolysis additional products, namely steel, diesel and char are also produced in addition to electricity. In the case of incineration, a fuel substitute for coal is produced. In the crumbing process shredded waste tyres are converted into rubber crumb which can be used by other industries to produce rubber products. The outputs from waste to energy conversion and crumbing are therefore possible substitutes for virgin commodities currently used by industries in their production processes. Kraftek involves the conversion of waste tyres into commodities for final consumption.

At present, the largest markets in South Africa for waste tyres are re-use (25 per cent); cutting or shredding (23 per cent); pyrolysis (18 per cent); and incineration (16 per cent). In 2015 approximately 71,806 tonnes of waste tyres were recycled in South Africa from about 16,037 tonnes in 2013 and 31,448 tonnes in 2014. In terms of recycling usage, crumbing, pyrolysis and incineration technologies account for the bulk of use, using approximately 46.5 per cent of waste tyre product in 2015 (REDISA interview, 2016). This paper focuses on the recycling of waste tyres using crumbing and pyrolysis and the added economic benefit of the development of extended producer responsibility initiatives.

3. Methodology

3.1 Literature

Many researchers have attempted to study the link between the economy and the environment, generally through extending standard input-output (IO) frameworks, either analytically or via satellite accounts, to model the flow of materials in the economy (Choi, 2012). Leontief (1970) was the first to illustrate the extension of IO models to include pollution and pollution abatement by amending the inter-industry table. Many studies followed, assessing a range of environmental issues including solid waste management and recycling (e.g. Huang et al., 1994; Pimenteira et al., 2005). IO models continue to be used broadly in waste management research. In 2002, Nakamura and Kondo, developed a waste IO (WIO) model which incorporates waste creation and management into the IO framework. WIO models have been used to analyse the costs associated with product life-cycles (Nakamura and Kondo, 2006a; Nakamura and Kondo, 2006b; Nakamura et al., 2009).

Miyata (1995, 1997) used a computable general equilibrium (CGE) model to analyse the waste-economic system. CGE models improve on IO analysis as they capture the inter-industry interactions but also explicitly model demand and supply effects including price responses. Miyata (1995) developed a waste-economic accounting matrix, an analytical extension of the standard social accounting matrix (SAM) that included the flow of waste. In his model, waste is generated by producers and consumers and treated by waste treatment activities who demand intermediate goods and services and production factor resources. The cost of waste treatment enters the production and cost functions of firms and therefore influences their production decisions and economy-wide prices.

In 1999, Miyata and Pang extended this work to include material transformation to assess the impact of a zero-emissions orientated society. They include waste and recycling in a computable general equilibrium framework using an economic-material accounting matrix (EMAM) for the economy of Aichi Prefecture in Japan. Similarly, to Miyata (1995), industrial and household waste is generated through the production of goods and services; and consumption respectively. Waste, however, is either treated and disposed of or transformed by either internal (within the industry but modelled as a separate activity) or external material transformation sectors. The external transformation sector consists of public and private waste abatement firms. Recycled waste is re-introduced into the economy for intermediate consumption.

While both IO and CGE models have been used in waste management studies, this paper follows the approach of Miyata and Pang (1999) and uses a CGE model for SA to assess the economic impacts of introducing tyre recycling into the South African economy.

3.2 CGE Model Description

We use the South African General Equilibrium (SAGE) model to estimate the economy-wide impacts of reintroducing recycled waste streams into the South African economy. SAGE is a dynamic recursive version of the static computable general equilibrium (CGE) model described by Lofgren et al. (2002) and was developed by the World Institute for Development Economics Research at the United Nations University. The model is based on a 2009 social accounting matrix (SAM) and includes 49 activities and 85 commodities. The SAM includes 4 labour groups by level of education and 14 expenditure-based representative households (Davies and Thurlow, 2013).

Behavioural equations capture the decision making process of industries and households who maximise profits and utility subject to costs and purchasing power respectively. Producers consume both domestic and imported intermediate goods and services as well as factors of production. Production factors include capital and labour. Intermediate goods and services consumption is governed by Leontief functions while the consumption of production factors is specified according to constant elasticity of substitution (CES) functions. As a result, fixed shares of goods and services are required in the production process, but production factors can be substituted according to changes in their relative prices.

Commodities are sold to other industries as intermediate inputs and to households, government and the rest of the world for final consumption. The level of commodities in domestic versus international markets is based on relative prices and is governed by a constant elasticity of transformation (CET) function. Similarly, the volume of goods and services imported is also based on relative prices and is governed by an Armington function. We assume that South Africa is too small to directly affect global prices which therefore remain fixed.

Households earn an income from providing labour and land and capital assets to industries and transfers from government and the rest of the world. Returns to foreign labour, land and capital are repatriated. Households consume both domestic and foreign commodities, pay taxes, transfer money abroad and save. Consumption is based on a linear expenditure system of demand.

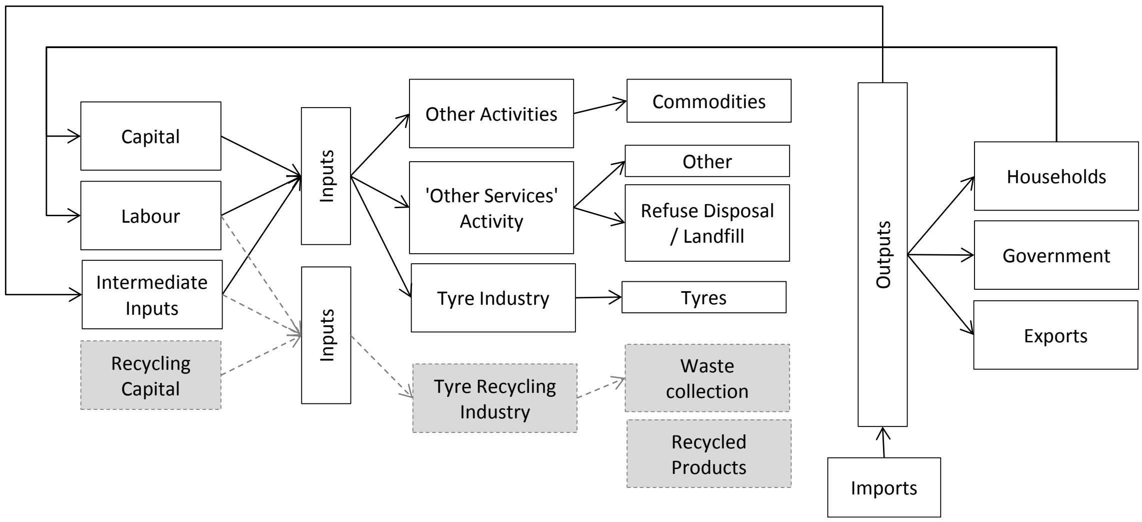
Structural equations ensure macro-economic consistency between incomes and expenditures within the model. Closure rules are used to describe the functioning of the economy; these include the behaviour of exchange rates, investment, government savings, prices and quantities of factors of production. In this exercise we assume that the exchange rate adjusts to absorb shocks to the economy while foreign savings remains fixed. The level of investment is determined by total savings in the economy (i.e. private, government and foreign). Government savings adjusts for changes in income and expenditure - all tax rates remain unchanged. The domestic price index is used as the model numeraire.

CGE models therefore simulate the functioning of a market economy and capture the direct and indirect linkages between different players (i.e. producers, households, government and rest of the world) while taking into account the impacts of relative price changes and respecting macroeconomic constraints. As such, it is a useful simulation laboratory for assessing the economy-wide impacts of shocks to the economy.

3.3 Including the Tyre Recycling Industry

To model the economy-wide impacts of the Waste Tyre Management Plan, we extend the 2009 SAM to display the disposal practices of waste tyres in South Africa. Prior to the introduction of the Waste Tyre Management Plan in 2012, waste tyres were primarily landfilled, burnt for heating or left lying in the open, adding little to no value to the economy. As a result, waste tyres formed part of the general waste removal function of municipalities. This function is captured in the supply and use table under the ‘other services’ activity (eurostat, 2016). In the baseline scenario, tyre producers use landfill services from the other services sector as an input into their production process. Tyre producers, however, were not responsible for the costs incurred in disposing of waste tyres. As a result, it is fair to suggest that these producers were implicitly subsidised by government in this regard. This subsidisation is captured in the model as a negative tax paid by tyre producers to government. As the cost of waste management is included in government's budget which is already accounted for in the SAM (as it uses national accounts information), government accounts are adapted where necessary to reflect any changes from the inclusion of the negative tax so that there is no change to the level of government spending and income. Figure 1 below illustrates this disposal practice in the baseline scenario.

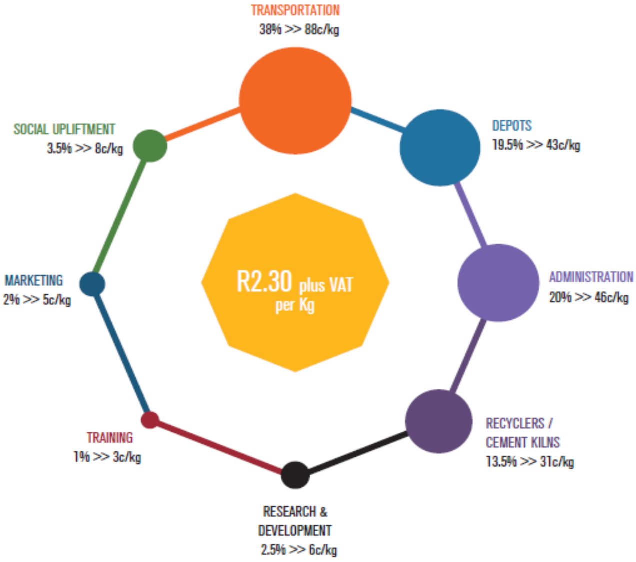
Figure 1: Illustrative diagram of waste disposal in the model baseline (resource flow)



Source: Authors' own model description

Introducing extended producer responsibility and the Waste Tyre Management Plan into the economy shifts the disposal of waste tyres away from landfilling and toward recycling (shaded blocks in Figure 1). The recycling of waste tyres consists of three key functions: the physical recycling production processes (i.e. crumbing, pyrolysis, tyre-derived fuel and kraftek); the collection, storage and transportation of waste tyres; and the management and coordination function of REDISA. Using information provided and approved by REDISA, we construct the technology vectors for these three functions and combine them using a weighted summation to develop the technology vector for the tyre recycling industry as a whole. This is included as a new sector into the 2009 SAM. Weights of the different functions of the Waste Tyre Management Plan are derived from REDISA's allocation of the waste management fee (see Figure 2).

Figure 2: Allocation of Waste Management Fee



Source: http://www.redisa.org.za/

The technology vector shows the tyre recycling industry to be highly labour intensive, particularly with respect to low skilled labour due to the demand for waste pickers. Expenditure on wages accounts for roughly 70 per cent of total expenditure. Intermediate goods and services expenditure is less than 20 per cent of total expenditure while capital accounts for approximately 10 per cent. The detailed technology vector is not presented here due to confidentiality.

In terms of output the tyre recycling industry provides a collection, transportation and storage service for waste tyres. Through the recycling production processes, however, the industry also produces rubber, steel, diesel, char (a substitute for coal) and other manufacturing products. The collection, transportation and storage service accounts for 57.5 per cent of the tyre recycling activities output, while the production of rubber (19.3 per cent), steel (9.9 per cent), diesel (7.2 per cent), coal (5.7 per cent) and other manufacturing activities (0.4 per cent) make up the rest of total output. We assume recycled products to be perfect substitutes to their virgin product counterparts. As a result, tyre recycling results in an increase in the supply of total commodity in the economy. Outputs from crumbing and pyrolysis processes flow back into the economy for intermediate consumption while Kraftek outputs are sold to final consumers.

4. Scenarios and Assumptions

4.1 Scenarios

Three scenarios were used to analyse the potential economic benefit of a waste tyre recycling industry in South Africa.

The first scenario, the baseline scenario, is a counterfactual where the Waste Tyre Management Plan is non-existent, activity in the tyre recycling industry and hence output from the industry is set close to zero. The share of tyres that were burnt and those that were landfilled prior to 2012 is difficult to ascertain, but after conducting interviews and field visits, it is estimated that 68 per cent of waste tyres were burnt and 29% were landfilled (REDISA team analysis). In the baseline, the tyre industry pays a negative tax of R0.57 per kilogram of tyre waste, to represent the effective subsidy that the industry receives for the waste tyres that are landfilled.

In scenario two and three (the recycling scenario), activity in the tyre recycling industry expands as tyre producers are obligated to use the services of the industry through the Tyre Waste Management Plan. Scenario two assess the short term impact of the Waste Tyre Management Plan, which has been operational since 2012. In this scenario about 25% (42 000 tonnes) of total tyre waste is recycled, and the technology vector reflects the activity of the tyre recycling industry from 2012 to 2015. Scenario three shows the full potential of the Waste Tyre Management Plan to October 2016 by assessing the impact of 100 per cent recycling (170 000 tonnes of waste tyres[5]). It is assumed that the bulk of recycling happens through crumbing activity (60%), which represents the REDISA target for 2020 (based on a similar assumption by McKinsey, 2015).

4.2 Assumptions

There are a number of assumptions that are made in the model setup that govern how the model reaches equilibrium. First, capital required for the tyre recycling industry is assumed to be available and therefore has no impact on general capital use and allocation in the economy. A new capital account is created for the tyre recycling industry. The industry must however compete with the rest of the economy for labour and intermediate goods and services. In terms of the labour market, high skilled labour is assumed to be fully employed, but free to move between sectors. This makes sense for the South African case, where a shortage of skilled labour does exist. Unskilled labour (workers that have not completed Matric) is assumed to be unemployed and therefore there is an adequate supply of unskilled labour to meet the increase in demand for labour in the scenarios. Lastly, the macroeconomic closures assumed are in accordance with the stylised facts of South Africa. A balanced savings and investment closure is assumed, which means that investment and government expenditure remains fixed shares of domestic demand. To mimic the foreign market in South Africa, a flexible exchange rate is assumed and no fiscal balance rule is imposed on the model. Government savings are assumed to be flexible and direct taxes are fixed.

[5] Worldwide around 16-18% of tyre mass is lost through the mass lost over the lifetime of a tyre. A loss of 25% is assumed here, from the prolonged use of tyres (20% loss) and another 10% lost as random, unrecorded use (lost to the informal market, turfed, or used as fuel) (REDISA Interview, 2016).

As a simplifying assumption based on the current tyre recycling industry, it is assumed that the outputs from Pyrolysis exclude electricity generation. This technology does not currently exist in South Africa however it is possible that electricity generation could be a potential output of this activity in future.

There are significant environmental and health benefits associated with recycling, and the economic benefits from these positive externalities are not quantified and included in this study. This presents an interesting case for future work.

5. Results

In summary, the introduction of the Waste Tyre Management Plan has several positive impacts on the economy:

- The introduction of the new industry provides additional value to the economy relative to the baseline scenario. As discussed earlier waste tyres were landfilled, burned or dumped adding no economic value. Through functions of the Waste Tyre Management Plan, value is added to the economy through the employment of labour and capital in each of these functions. The assumption of unconstrained capital to the sector drives the result illustrated in
- Figure 3. If capital were not as easily available to the sector, the economic impacts would be smaller.
- The supply of total commodities in the economy increases due to the production of recycled products. This reduces the prices of these commodities, providing a positive stimulus to the economy. The additional supply of commodities also stimulates exports.
- The tyre recycling industry provides a new source of demand to the economy. This may have a positive impact on other sectors if they are able to increase their output. Alternatively, it could result in an increase in imports.
- Factor employment opportunities created in the tyre recycling sector increases household incomes. This leads to an increase in consumption as well as savings. Households are assumed to save a fixed proportion of their incomes. The increase in savings in the economy raises the level of funds available for investment.
- Government spending also increases as the shift toward extended producer responsibility reduces the financial burden on government as producers are now paying for the disposal of their products.

The impact on the economy is however, limited by resource constraints in the economy. The key constraint in this analysis is the availability of skilled labour. The tyre recycling industry must compete with the rest of the economy for skilled labour, raising their costs and hence dampening the impact on production and output.

5.1 GDP and employment

Redirecting the use of waste tyres from landfills to tyre recycling through crumbing and pyrolysis has a positive impact on economic activity and employment in South Africa. Under a 25 per cent recycling scenario, real GDP is estimated to increase by 0.002 per cent relative to the baseline scenario. An additional 346 jobs are created, primarily in unskilled labour categories. Under a full recycling scenario, this impact is larger. Real GDP increases by 0.005 per cent relative to the baseline and an additional 1448 jobs are created.

Figure 3: Economic and Employment Impacts

	25% Tyre Recycling	100% Tyre Recycling
GDP	**0.002**	**0.005**
Private Consumption	*0.001*	*0.004*
Gross Fixed Capital Formation	*0.002*	*0.005*
Government Consumption	*0.002*	*0.007*
Exports	*0.001*	*0.006*
Imports	*0.001*	*0.005*
Employment*	**346**	**1448**
**Number of additional jobs. All other results are per cent deviation from baseline.*		

Source: CGE Model Results

The increase in real GDP is largely driven by an increase in private consumption expenditure, which rises by 0.004 per cent relative to the baseline scenario. The rise in private consumption is driven by higher household incomes from increased employment and higher wages. As discussed above we assume, in line with the stylized facts for South Africa, the higher skilled labour supply is fixed and cannot increase while an excess of unskilled labour exists. Employment of lower skilled workers therefore increases, while wages of higher skilled workers rise. Household incomes, particularly in higher income households, are also increased by additional returns to capital. Household savings increase due to higher incomes. This rise in households' savings coupled with the increase in government savings from higher tax revenues increases investment by 0.005 per cent relative to the baseline scenario.

Exports increase by 0.006 per cent relative to the baseline. The increase in exports is concentrated in the manufacturing industry, which benefits from the increase in supply of commodities available to them for intermediate use. For example, steel produced through the pyrolysis process increases the total supply of steel for intermediate use as it is substitutable for virgin steel. Imports rise due to increased production (which increases the demand for imported intermediate input commodities) as well as higher private household consumption.

5.2 Sector Impacts

The manufacturing sector experiences the largest gains in real gross value added, which increases by 0.037 per cent relative to the baseline. The increase in value added is driven by increased activity in other manufacturing due to increased production by the tyre recycling industry. Metal product industries, namely non-ferrous metals, iron and steel and other metal products also experience significant increases in gross value add, followed by food and beverages. The textiles and chemicals industries experience a decrease in value added. The rubber industry, in particular, experiences the largest decrease in gross value add due to the direct increase in production costs from the waste management fee.

Mining and quarrying; and agriculture, fishing and forestry experiences increases in gross value add due to their interlinkages with the rest of the economy. The mining and quarrying sector benefits from a depreciation in the real exchange rate. This also provides a stimulating impact for other exporters such as those in the metal product sector.

Figure 4: Sector Impacts

	25% Tyre Recycling	100% Tyre Recycling
Agriculture, Fishing and Forestry	**0.001**	**0.004**
Mining and Quarrying	**0.002**	**0.010**
Manufacturing	**0.010**	**0.037**
Services	**-0.001**	**-0.002**
All other results are per cent deviation from baseline.		

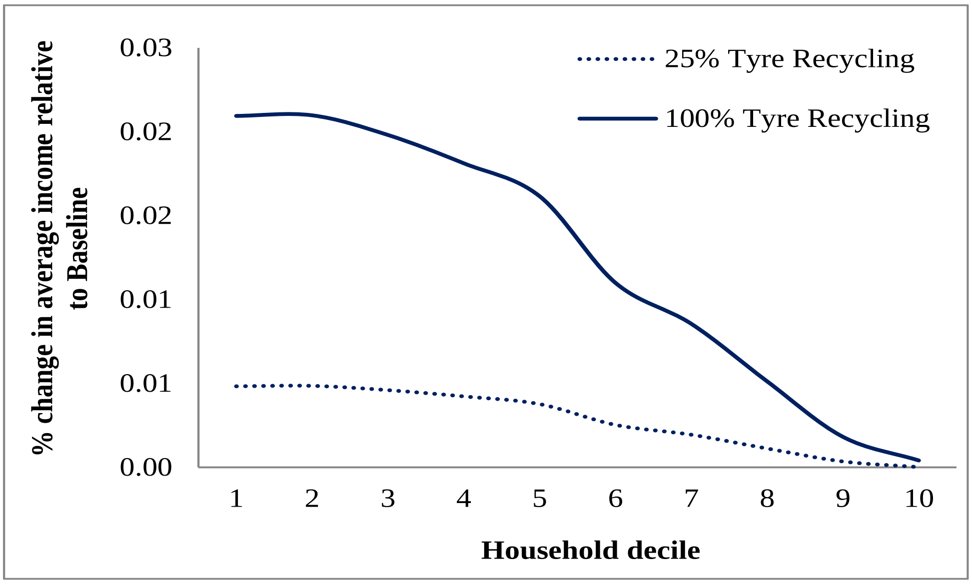
Source: CGE Model Results

Gross value added in the services sector decreases relative to the base case. This is largely due to the decrease in municipal waste disposal services for waste tyres. The tyre recycling industry demands labour and capital factors in its production process. As noted in the assumptions, high skilled labour is assumed to be in fixed supply. The increase in demand for high skilled labour raises the price of labour. This negatively affects other industries as high skilled workers shift to other more profitable sectors. The services sector is skilled labour intensive as a result the sector is negatively affected by the rise in wages.

5.3 Welfare

Overall, household real incomes increase by 0.02 per cent under the 25 per cent recycling scenario and 0.1 per cent under the 100 per cent recycling scenario. The rise in income is concentrated at the lower end of the household income distribution as illustrated in Figure 5. This result is due to the increase in employment of lower skilled workers due to a) employment in the tyre recycling industry and b) increased employment in benefitting sectors such as metal product manufacturing. Overall, household real consumption levels also increase, following a similar distribution to that of income gains. Increases in real consumption are however dampened by an overall increase in prices in the economy as higher wage costs increase prices in many sectors.

Figure 5: Welfare Impacts



6. Modelling Challenges

There are a number of challenges associated with adding a new sector to the SAM. Essentially the way that a sector is included in the SAM represents the linkages between that sector and all other economic agents in the economy. This exercise is therefore data and information intensive, and requires knowledge of the demand and supply intricacies of the potential waste recycling sector.

A recycling sector already exists in the 2009 SAM, although the sector doesn't capture the potential role of REDISA, and the different waste transformation activities, namely waste to energy, crumbing and Kraftek. There were therefore three approaches that were explored for including tyre waste recycling in the SAM: (a) Include recycling of waste tyres in a SAM that already contains recycled rubber in an existing recycling industry; (b) Include a completely new waste recycling and transformation sector in the economy, with a new commodity 'waste tyres'; (c) Include a completely new waste tyre recycling industry with waste tyres coming from stocks that already exist in the SAM.

In summary, the main challenges with adding the waste tyre recycling industry were ensuring that:

- There was adequate demand for both recycled and virgin products,

- Other sectors were not distorted as a result,
- There was adequate capital available in the economy,
- Labour was able to move between existing sectors and the new recycling industry,
- The transaction costs and expected selling prices were correct;
- Changes in taxes and resultant changes to government income were accounted for.

This analysis greatly improves on the initial attempt at simply increasing the supply of goods through recycling. The addition of a recycling industry for waste tyres has potential for job creation, enterprise development and a positive macroeconomic impact of value addition along waste stream value chains. This analysis, however, could be further improved by moving to a dynamic CGE model, where the investment in the waste recycling sectors would add to capital stock, and further add to growth and development over time.

As mentioned in the Phase 1 report, there are also a number of social and environmental costs that are borne from the disposal of waste in landfills and uncontrolled burning, including impacts on health, greenhouse gas emissions, soil and water contamination to name a few. This analysis does not quantify these externalities, and it would be interesting to explore and account for these in the 'true' cost of landfill waste in future work.

7. Conclusion

In conclusion, this paper presents an extension to a static CGE model for South Africa for the inclusion of a tyre waste recycling industry. The analysis shows that overall there is a slight positive impact from the Tyre Waste Management Plan from the introduction of a new industry, increase in supply of commodities in the economy, source of demand in the economy, employment creation and increased government spending. This analysis clearly shows the catalytic impacts from expanding the recovery and recycling industries that aren't seen in a simple supply shock.

In a scenario where 100 per cent of available tyre waste is recycled, approximately 1448 jobs could be created compared to a scenario with zero recycling. A large portion of the employment opportunities are created for unskilled workers, with significant positive impacts on welfare for low-income households. This result includes the knock-on effects of developing a waste recycling industry, compared to the simple supply shock in Hartley, Caetano and Daniels (2016). The manufacturing sector has the largest gains of 0.037 per cent against the baseline, driven by the increase in production by the new tyre recycling activity.

The results from this analysis are likely to be underestimating the potential economic benefits given that, first, the environmental benefits associated with recycling have not been quantified and accounted for. The waste management fee raises the private marginal cost of the producer so that it is equivalent to the social marginal cost, internalising the waste externality. Second, the analysis is static and not dynamic, therefore the impacts could be larger if the capital accumulation between periods was accounted for.

On the other hand, the results would be less positive if the new recycling industry were to compete for capital with other sectors, rather than the assumption that the capital available to the sector is available. If the recycled commodities are not substitutable for virgin commodities, as is assumed in the scenarios, this would have a negative impact on the results.

8. References

Choi, T. 2012. *Economic and Environmental Input-Output Modeling: Building Material Recycling*. Ph.D. thesis, Georgia Institute of Technology.

Davies, R. and Thurlow J. 2013. *A 2009 social accounting matrix for South Africa.* Washington DC, USA: International Food Policy Research Institute. Accessed on 15 July 2016: http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128029

DST (Department of Science and Technology). March 2014. The economic benefits of moving up the waste management hierarchy in South Africa: The value of resources lost through landfilling. A National Waste Research, Development and Innovation Roadmap for South Africa: Phase 2 Waste RDI Roadmap. Pretoria, South Africa: Department of Science and Technology.

Eurostat, 2016. Eurostat Supply and Use Tables. Accessed on 30 September 2016: http://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/methodology/supply-use-tables.

Hartley, F., Caetano, T. and Daniels, R.C. 2016. The general equilibrium impacts of monetising all waste streams in South Africa. Energy Research Centre. University of Cape Town. November 2016.

Huang, G.H., Anderson, W.P., & Baetz, B.W. 1994. Environmental input-output analysis and its application to regional solid-waste management planning. Journal of Environmental Management, 42(1), 63-79.

Leontief, W. 1970. Environmental repercussions and the economic structure: An input-output approach. The Review of Economics and Statistics, 52(3), 262-271.

Lofgren, H., Harris, R.L. and Robinson, S. 2002. *A standard computable general equilibrium (CGE) model in GAMS.* Washington DC, USA: International Food Policy Research Institute.

McKinsey & Company. 2015. REDISA Integrated Environmental Economic Impact Assessment. Confidential Report. Mimeo: McKinsey & Company.

Miyata, Y. 1995. A General Equilibrium Analysis of the Waste-Economic System - A CGE Modeling Approach. Infrastructure Planning Review, 12 : 259-270.

Miyata, Y. 1997. An Intertemporal General Equilibrium Analysis of the Waste-Economic System, Infrastructure Planning Review, 14 : 421-432.

Miyata, Y. and Pang, X. 1999. *A General Equilibrium Analysis of the Economic-waste System with Material Recycling - A CGE modelling Approach*. 39th Congress of the European Regional Science Association: Regional Cohesion and Competitiveness in 21st Century Europe, August 23 - 27, 1999, Dublin, Ireland.

Nakamura, S., and Kondo, Y. 2002. Input-Output Analysis of Waste Management. Journal of Industrial Ecology, 6(1), 39-63.

Nakamura, S., and Kondo, Y. 2006a. A waste input-output life-cycle cost analysis of the

recycling of end-of-life electrical home appliances. Ecological Economics, 57(3), 494-506.

Nakamura, S., and Kondo, Y. 2006b. Hybrid LCC of appliances with different energy efficiency. The International Journal of Life Cycle Assessment, 11(5), 305 - 314.

Nakamura, S., Nakajima, K., Yoshizawa, Y., Matsubae-Yokoyama, K., and Nagasaka, T. 2009. Analyzing polyvinyl chloride in Japan with the waste input–output material flow analysis model. Journal of Industrial Ecology, 13(5), 706-717.

Pimenteira, C.A.P., Carpio, L.G.T., Rosa, L.P., and Tolmansquim, M.T. 2005. Solid wastes integrated management in Rio de Janeiro: input-output analysis. Waste Management, 25(5), 539-553.

REDISA. Information and data from discussions with REDISA employees, and online at http://www.redisa.org.za/