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The general equilibrium impacts of monetising all waste streams in South Africa[1]

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Key points

- This report estimates the potential economic impacts of the introduction of resources back into the economy through recycled waste streams in South Africa. As a first attempt, we estimate the impact of an exogenous increase in supply of recycled commodities through thirteen key waste streams.

- Reintroducing recycled commodities into the economy has the potential to increase domestic supply and lower prices of these commodities, stimulate demand and increase overall production.

- Depending on the level of recycling, real GDP could increase by up to 0.5 per cent with 13 661 new full-time equivalent jobs created, predominantly in lower skilled occupations, thus raising overall welfare.

- These results may be understated, as they do not include the catalytic impacts from expanding recovery and recycling industries. However, the expansion of these industries may also come with additional costs.

- The results in this paper suggest that South Africa can significantly alter its current economic growth trajectory in the short-term to a lower-skilled and more employment-intensive path, using waste beneficiation as the strategy to achieve it.

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1. Introduction

The recovery, recycling and reuse of waste materials are potential sources of economic activity and employment in South Africa. Waste materials if recycled can be reintroduced into the economy, increasing the supply of intermediate and final goods. This could result in lower prices as a) total supply in the economy increases and b) the supply of recycled goods could possibly be introduced at reduced prices. Recovery and recycling furthermore provide opportunities for new industries, labour absorption as well as a production catalyst through its demand for intermediate goods and services.

In 2011, the Department of Environmental Affairs estimated that approximately 90 per cent (90.2 million tons) of generated waste was landfilled with only 10 per cent recycled (DEA, 2012). In 2014, the Department of Science and Technology (DST) investigated the value of resources lost through landfilling. It estimated that in 2011 a potential R17 billion worth of commodities were landfilled with only R8.2 billion recovered and reintroduced into the economy (DST, 2014).

This report estimates the economy-wide implications of reintroducing recycled waste streams in South Africa. As a first attempt, we estimate the impact of an exogenous increase in supply through the reintroduction of recycled commodities[5]. The monetisation of 13 waste streams by the DST for three scenarios inform the supply shocks implemented.

The benefits and costs associated with the introduction of industries that recover and recycle waste streams are not considered in this study. As a result, it is likely that the impacts are understated as the analysis does not account for the catalytic impacts on the economy from increased intermediate goods and services demand, higher net employment[6] and lower waste disposal costs. Further, the additional positive implications of the environmental benefits are not quantified. However, including the recovery and recycling industries for the various waste streams would also bring in additional costs (i.e. financing of investment, opportunity costs of resource use, etc.), currently not incorporated. This could have an offsetting impact. These issues are investigated for a single waste stream in Hartly, Caetano & Daniels (2016), but are not explored in this paper.

2. Methodology and Assumptions

2.1 Model

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 (see Diao and Thurlow (2012) for a description of the core structure and dynamics).

The model uses 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, 2009).

CGE models 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.

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[5] An increase in supply given that there is an increase in the units of recycled commodities in addition to the virgin commodities produced by sectors. This is illustrated by a movement of the supply curve to the right for waste stream sectors.

[6] Note that all employment effects estimated in this paper are for full-time equivalent (FTE) jobs.

2.2 Scenarios

In 2011, the DST monetised 13 waste streams in South Africa for three recycling scenarios (see Table 1). These scenarios form the basis of the scenarios considered in this report. We use Scenario 1, which describes the recycling of waste streams in 2011, to inform the shares of recycled commodities in the baseline scenario (referred to as Scenario 1).[7]

The DST estimates that if the share of waste materials recycled increased to 29 per cent (Scenario 2) from 11 per cent (Scenario 1), the value of the commodity reintroduced into the economy would rise to R12.8 billion. If the share of waste materials increases to 47 per cent (Scenario 3), R17.4 billion worth of commodity would be reintroduced into the economy and if all waste were recycled and reintroduced (Scenario 4), the value would increase by three times the initial value to R25.2 billion.

The largest potential sources for waste stream recovery in value terms identified by the DST are biomass waste from industry; plastic; municipal waste; and metals. Increasing the recycled share of these waste streams to 100 per cent would raise the value of commodities reintroduced into the economy by 156 per cent, accounting for 83 per cent of the potential increase in total waste stream value.

Table 1: Potential resource value (per year) under different scenarios for resource recovery

	Quantity recovered (million t/year)				Price (R/t)	Value (2013 Rand million/year)			
Stream	Scenario 1	Scenario 2	Scenario 3	Scenario 4		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Municipal waste (non-recyclable portion)	0.0	2.0	4.0	8.1	367.4	0.0	740.5	1481.1	2962.2
Organic component of municipal waste	1.1	1.6	2.1	3.0	188.6	199.6	299.4	399.2	570.3
Biomass waste from industry	0.0	10.9	21.7	36.2	188.6	0.0	2046.9	4093.8	6823.0
Construction and demolition waste	0.8	1.6	2.4	4.7	87.5	66.2	136.5	206.7	413.5
Paper	1.0	1.1	1.4	1.7	744.5	736.0	809.6	1033.0	1291.2
Plastic	0.2	0.5	0.8	1.3	3119.5	734.8	1677.8	2449.4	4082.3
Glass	0.3	0.4	0.6	1.0	490.0	150.5	204.6	282.2	470.3
Metals	2.5	2.7	2.8	3.1	2270.0	5668.1	6022.4	6376.6	7085.1
Tyres	0.0	0.1	0.2	0.2	367.0	3.6	38.0	72.4	90.5
WEEE	0.0	0.0	0.0	0.1	1000.0	6.9	19.5	32.0	64.0
Slag	2.7	3.4	4.0	5.4	175.0	470.0	587.4	704.9	939.9
Ash	2.3	4.8	7.2	36.2	3.0	6.9	14.3	21.7	108.7
Waste oils	0.1	0.1	0.1	0.1	2777.8	146.7	193.3	240.0	333.3
Total	10.9	29.0	47.4	101.1		8189.2	12790.2	17393.1	25234.4
Percent change from Scenario 1		166.6	335.0	828.9			56.2	112.4	208.1

Source: DST, 2014

To estimate the economy-wide impacts of increasing the shares of recycled waste materials reintroduced into the economy, we map the waste streams to commodities within the SAM. Waste streams are mapped based on their potential uses within the economy as identified by the DST (DST, 2014). In some cases, simplifying assumptions were made about the potential commodities from recycled waste streams.[8] All values are deflated to 2009 Rands for consistency with the SAM. Table 2 illustrates the mapping used.

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[7] The DST estimates are used as in the paper apart from deflating the values to 2009 prices. The SAM is assumed to include the recycling activities as in Scenario 1, therefore any increase in supply of recycled commodities is compared to this Baseline SAM.

[8] An example of this is waste electric and electronic equipment, which has the potential to feed into numerous commodity streams due to its composition. For purposes of this analysis, only the three largest components, which account for 75 per cent, are considered.

Table 2: Waste stream to SAM mapping

	CGE Model Commodities									
Waste Streams	Electricity & gas distribution	Cement	Paper products	Plastics	Glass products	Basic iron & steel	Non-ferrous metal	Other rubber products	Construction	Petroleum products
Municipal waste (non-recyclable)	100%									
Organic component of municipal waste	100%									
Biomass waste from industry	100%									
Construction and demolition waste		100%								
Paper			100%							
Plastic				100%						
Glass					100%					
Metals						85%	15%			
Tyres								100%		
WEEE				17%		25%	44%			
Slag (from mineral processing)									100%	
Ash (from power generation)									100%	
Waste oils										100%

Source 1: Own calculations based on DST (2014)

While most waste streams tend to increase the supply of individual commodities, some like WEEE[9] and metals have an impact on more than one commodity. For these waste streams, we assume fixed shares for commodities per unit of waste. For example, increasing the recycling of WEEE to 100 per cent would increase the supply of reintroduced plastics; basic iron and steel; and non-ferrous metals by 17, 25 and 44 per cent, respectively. Under such a scenario, the total supply of plastics; basic iron and steel; and non-ferrous metals would increase by 0.04, 0.03 and 0.02 per cent.

Table 3 illustrates the shocks implemented under the different scenarios. The full recovery of some individual waste streams has a sizeable impact on the supply of commodities. For these waste streams, we conduct an individual analysis of the waste stream to understand their impacts. These waste streams have been identified as, (i) waste to energy[10]; (ii) plastics; (iii) construction and demolition waste (or increase in cement); and (iv) glass.

Table 3: Supply shocks by scenario

Per cent change in commodity supply	Waste Stream Scenario						
	Scenario 2	Scenario 3	Scenario 4	Electricity*	Plastics	Cement	Glass
Electricity & gas distribution	1.9	3.9	6.8	6.8			
Cement	0.2	0.4	1.0			1.0	
Paper products	0.1	0.3	0.6				
Plastics	1.7	3.0	5.9		5.9		
Glass products	0.4	1.0	2.4				2.4
Basic iron & steel	0.2	0.4	0.7				
Non-ferrous metal	0.1	0.2	0.3				
Other rubber products	0.4	0.8	1.0				
Construction	0.0	0.0	0.1				
Petroleum products	0.0	0.1	0.1				

*Electricity refers to waste streams Municipal waste, Organic component of municipal waste and Biomass waste from industry.

Source: Own calculations based on DST (2014) and 2009 SAM

2.3 Assumptions

As noted earlier, in this analysis we do not account for the benefits and costs associated with the introduction of recycling industries that would undertake the recovery and recycling of waste streams. We impose a supply shock through technological change. Production is therefore not directly changed but rather affected through general equilibrium effects.

The macroeconomic closures assumed are aligned to the stylised facts of South Africa. A balanced savings-investment approach is taken, as such investment and government expenditure remains

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[9] WEEE: Waste Electrical and Electronic Equipment.

[10] These include municipal waste, organic component of municipal waste and biomass waste from industry. For simplicity, it is assumed that the increase in waste to energy provides inputs for the electricity and gas distribution sector directly.

fixed shares of absorption. A flexible exchange rate is assumed and no fiscal balance rule is imposed. High skilled labour (Grade 12 and higher) is assumed to be scarce and therefore always employed. There is an excess supply of lower and middle level skilled (Grade 11 and lower) labour. All labour and capital is mobile across sectors.

3. Results

3.1 DST Scenarios

This section presents the results from the DST scenarios, where recovery and recycling are increased for all waste streams simultaneously. The results from the DST scenarios are compared to Scenario 1, the baseline scenario, and are presented in Table 4.

Table 4: Summary table of results from DST shocks

	Scenario 2	Scenario 3	Scenario 4
GDP	**0.13**	**0.27**	**0.48**
Private Consumption	*0.15*	*0.31*	*0.55*
Gross Fixed Capital Formation	*0.14*	*0.28*	*0.53*
Government Consumption	*0.04*	*0.07*	*0.13*
Exports	*0.15*	*0.30*	*0.56*
Imports	*0.14*	*0.28*	*0.52*
Agriculture, Fishing and Forestry	0.05	0.11	0.18
Mining and Quarrying	-0.29	-0.58	-1.10
Manufacturing	0.19	0.37	0.66
Services	0.06	0.12	0.21
Employment*	3,879	7,630	13,661
Average wage	0.11	0.21	0.38
*Number of additional jobs. All other results are per cent deviation from baseline.			

3.1.1 GDP

The exogenous commodity shock has a positive impact on real GDP, which increases by between 0.13 per cent in Scenario 2 and 0.48 per cent in Scenario 4, relative to Scenario 1. The increase in waste to electricity and plastics recycling adds the most to value of the 13 waste streams considered due to their sizeable impacts on the supply and price of commodities.

Of the components of GDP, consumption and gross fixed capital formation (GFCF) experience the largest increases and drive the change in real GDP. Private consumption increases due to higher incomes as employment and average wages in the economy rises. The increase in private consumption ranges from 0.15 per cent in Scenario 2 to 0.55 per cent in Scenario 4. Tax revenue increases by between 0.14 and 0.51 per cent in Scenario 2 and Scenario 4 primarily due to increased consumption, resulting in an improved fiscal balance. This along with increased private savings (from higher wages and firm profitability) reduces the cost of investment. As a result, GFCF increases by between 0.14 per cent in Scenario 2 to 0.55 per cent in Scenario 4.

Although the reintroduction of recycled commodities into the economy lowers the domestic price of these goods, overall consumer prices increase as the rise in final demand exceeds the increase in supply. Economy-wide prices increase by 0.01 per cent in Scenario 2 and 0.03 per cent in Scenario 4, relative to Scenario 1.

3.1.2 Sector Growth

Through the various linkages and due to constraints on the economy, there are a number of findings that should be highlighted at the sectoral growth level. As previously mentioned, the overall impact on the economy was positive, and GDP increases with an increase in reintroduction of recycled commodities.

The impact on domestic production of commodities affected by waste recycling is dependent on the ability of the private consumption, investment demand and foreign demand to absorb the increase in supply. In the case of the electricity and plastics sectors, there is a decrease in domestic production as the demand for virgin product declines. There is a notable decrease in the level of coal mining activity due to the decrease in coal-fired power generation. Mining and quarrying GVA declines by 0.29 per cent in Scenario 2, 0.58 per cent in Scenario 3 and 1.1 per cent in Scenario 4.

Sectors that are the largest users of the recycled commodities experience an increase in GVA, as lower commodity prices decrease their cost of production and increase their profitability. The provision of electricity at lower prices creates a favourable environment for electricity intensive users such as non-ferrous metals; and iron and steel, who experience an increase in GVA by between 1.6 per cent in Scenario 2 and 5.8 per cent in Scenario 4; and 0.5 per cent in Scenario 2 and 2 per cent in Scenario 4, respectively. This, along with benefits resulting from the reintroduction of other recycled commodities, drives the increase in manufacturing activity. Manufacturing GVA increases by 0.19 per cent in Scenario 2 and 0.66 per cent in Scenario 4.

Agricultural and services GVA increases as the intermediate demand for these goods and services rise. Agricultural GVA increases by between 0.05 per cent in Scenario 2 and 0.18 per cent in Scenario 4, while services GVA increases by between 0.06 and 0.21 per cent.

3.1.3   Trade
The exogenous increase in recycled commodity supply decreases the domestic price of these goods and makes them more competitive for trade. Lower domestic prices also favourably affect the competitiveness of benefiting sectors. Total exports in Scenario 4 increases by almost 0.6 per cent relative to Scenario 1, while in Scenario 2 and 3 it is 0.15 and 0.3 per cent higher respectively. The rise in exports is largely driven by increased exports of non-ferrous metals; basic iron and steel; basic chemicals and plastics.

While some export sectors benefit from lower recycled induced prices, there are negative impacts on others, such as the "other mining" sector, as they cannot compete for factor resources due to high factor prices. Exports of other mining products decrease by 1.5 per cent. Domestic supply is insufficient to meet domestic demand at internationally competitive prices. Imports for other mining products therefore increase by 1.32 per cent. The rise in exports causes an appreciation in the real exchange rate. This reduces the prices of foreign goods and some commodities. Total imports increase by 0.52 per cent in Scenario 4; 0.28 per cent in Scenario 3; and 0.14 per cent in Scenario 2, relative to Scenario 1.

3.1.4   Employment and Wages
The increase in activity resulting from lower prices in the economy raises the demand for factors of production. Total full-time equivalent (FTE) employment in the economy increases by 3 879 jobs in Scenario 2 relative to Scenario 1. Due to more significant price reductions in Scenario 3 and 4, employment increases at a larger scale with 7 630 and 13 661 additional jobs created respectively. This employment is focused on lower skilled labour, where an excess supply of labour exists. Non-ferrous metals; basic iron and steel; and basic chemicals experience the largest increases in employment.

In the case of higher educated workers, the supply constraint raises the average wage as firms compete for these workers. Average wages are found to increase by 0.1 per cent in Scenario 2 and almost 0.4 per cent in Scenario 4, relative to Scenario 1. The constraint on high skilled labour supply, along with capital, limits the ability of the economy to expand as it raises production costs and reduces firm profitability.

3.1.5   Households
On aggregate households experience an increase in income of between 0.17 and 0.6 per cent for Scenario 2 and Scenario 4, relative to Scenario 1. The rise in incomes is driven by increased returns to production factors (i.e., labour and capital) as well as increased levels of employment. This increase however is offset partially through an overall rise in relative prices in the economy.

Economy-wide consumer prices increase by between 0.008 and 0.029 per cent in Scenario 2 and Scenario 4 as demand for resources, goods and services outstrips supply.

In terms of income distribution, wealthier households experience a marginal benefit as they are generally the owners of capital and supply the largest share of high skilled labour. The benefit to higher income households is amplified in Scenario 4 due to the larger impact of the constraint on labour and capital supply.

Figure 1: Change in household incomes
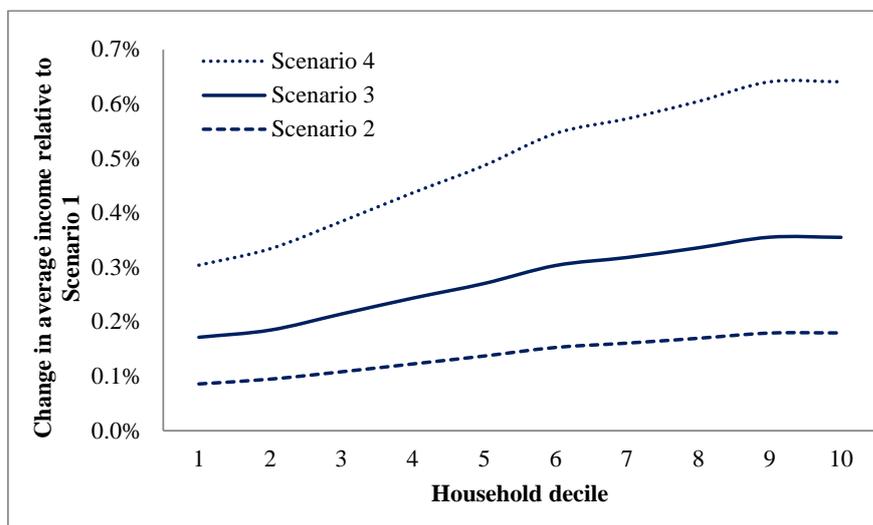
3.2 Individual Waste Streams

In this section, we discuss the results for exogenous commodity supply shocks for the individual waste streams that have the largest impact on the DST scenario results. These results are presented in Table 5.

Table 5: Individual waste stream results

	Electricity	Plastics	Cement	Glass
GDP	**0.29**	**0.09**	**0.01**	**0.01**
Private Consumption	*0.36*	*0.11*	*0.00*	*0.01*
Gross Fixed Capital Formation	*0.24*	*0.10*	*0.03*	*0.01*
Government Consumption	*0.08*	*0.02*	*0.00*	*0.00*
Exports	*0.34*	*-0.01*	*0.01*	*0.00*
Imports	*0.32*	*-0.01*	*0.01*	*0.00*
Agriculture, Fishing and Forestry	0.16	0.10	0.00	0.00
Mining and Quarrying	-0.29	-0.28	-0.01	-0.03
Manufacturing	0.44	-0.01	-0.01	0.00
Services	0.13	0.04	0.00	0.00
Employment*	8,605	2,766	234	162
Average wage	0.23	0.07	0.01	0.01
*Number of additional jobs. All other results are per cent deviation from baseline.				

3.2.1 Electricity generating waste

The combustion of municipal waste (including the organic component) and biomass waste from industry is a potential source of electricity supply through waste to energy. According to the DST, waste to energy accounted for 0.13 per cent of total electricity supply in 2011 and was primarily sourced through the organic component of municipal waste. Fully recycling municipal waste and biomass from industry has the potential to increase electricity supply by 6.8 per cent.

An exogenous increase in the supply of electricity decreases electricity prices as supply exceeds demand.[11] At the same time, the decrease in domestic prices coupled with the increase in supply reduces the need to import. Imports of electricity decline by 2.6 per cent relative to the baseline scenario. Tax revenue increases due to the increase in supply, which broadens the sales tax base.

Cheaper electricity prices lower producer costs; and particularly favour energy intensive users who are largely in the manufacturing sector. Manufacturing production increases by 0.4 per cent relative to the baseline scenario with non-ferrous and chemical sub-sectors experiencing the largest increases in activity (3.2 and 2 per cent, respectively). The expansion in output by electricity intensive users raises the cost of production factors as demand by these industries increase. Because the supply of highly skilled labour is constrained, wages increase on average by 0.2 per cent relative to the baseline scenario. The expansion of domestic production is constrained by high skilled labour and capital supply.

The additional source of electricity supply, along with the higher costs of capital and labour, results in less electricity production from coal fired plants. As a result, coal production also decreases relative to the baseline.

Increased returns to labour and capital, coupled with the higher employment of lower skilled workers, raises household incomes and consumption. The limited ability of the economy to meet the rise in demand however results in increased imports. Despite the appreciation in the exchange rate, exports increase as South African firms become more competitive, particularly in the production of electricity; non-ferrous; and basic chemicals commodities.

On aggregate, real GDP in the economy increases by 0.3 per cent, relative to the baseline with approximately 9 000 jobs created.

3.2.2 Construction and demolition waste

Construction and demolition waste consists of a wide range of materials. A study in the Western Cape estimated that 33.3 per cent of this waste is made up of concrete and masonry, 25 per cent of wood, and 12.5 per cent of drywall (Viljoen 2010, in DST 2014). In the baseline scenario, 16 per cent of the construction and demolition waste is recycled, with majority of the crushed recycled aggregate currently used as backfill in construction, as a substitute or together with cement depending on the use.

An exogenous increase in the supply of cement, as a main input commodity for construction (60 per cent of overall intermediate demand for cement product), results in a slight increase in GDP of 0.01 per cent overall. Unlike the other individual waste streams, there is no direct demand for cement from private households. The use of cement is accounted for by the demand for construction services by households. The increase in GDP is therefore driven directly by investment, which increases by 0.03 per cent against the baseline scenario, rather than private consumption.

The increase in supply of cement results in a decrease in the price of cement by 0.88 per cent, along with a decrease of 0.05 per cent in the price of construction. Given that construction is a key investment commodity in the economy, there is an increase in domestic demand and production for both construction and cement.

There are favourable impacts on a number of sectors as their production costs drop and they become more profitable. Resources shift to profitable sectors. As a result, less profitable sectors, such as non-ferrous metals; wood products; and forestry are negatively affected. Total capital declines by 0.4 per cent for non-ferrous metals, 0.11 per cent for wood products and 0.03 per cent for forestry. There are also negative employment impacts for these sectors with jobs in the non-ferrous metals sector decreasing by 0.4 per cent.

The decrease in the price of cement, along with a slight depreciation of the Rand has a positive impact on trade, as cement exports increase by 4.5 per cent and imports decrease by 0.65 per cent.

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[11] We assume that electricity prices are reflective of market conditions (i.e. supply and demand).

The positive impact on the economy of relatively cheaper cement and construction has an overall positive impact on employment with 234 jobs created due to the reintroduction of recycled construction and demolition waste.

3.2.3 Plastics

In Scenario 1, the 18 per cent of plastic waste recycled is assumed to account for 1.3 per cent of total plastics produced in South Africa. Increasing the share of plastic waste recycled to 100 per cent has the potential to increase domestic plastic supply by 5.9 per cent causing a decrease in prices of almost 4 per cent. Overall, this has a small positive impact on GDP, which increases by 0.09 per cent relative to Scenario 1.

The increase in GDP is driven by the rise in private consumption demand as household incomes increase due to increased employment and average wages; and in the case of wealthier households increased returns to capital. Employment increases by almost 3 000 jobs, while average wages increase by 0.07 per cent relative to Scenario 1.

Lower plastics prices favourably affect intermediate consumers by lowering production costs and increasing profitability. Benefitting sectors, which include medical equipment; motor vehicles and parts; and other chemicals, expand production and demand more labour and capital resources. This results in an increase in the return to these factors where supply is constrained. Resources shift away from less profitable sectors such as non-ferrous metals; other mining; and basic chemicals. Commodities from these sectors are largely exported. As a results exports decline despite the marginally weaker real exchange rate and increased plastics exports.

The rise in supply reduces the need for as much virgin product, which results in lower domestic production, and fewer imports. Imports of plastics declines by 6.4 per cent. This coupled with lower motor vehicle and parts imports reduces total imports by 0.01 per cent.

3.2.4 Glass

Whilst glass is a product that can theoretically be recycled an infinite number of times, the DST report assumes that only the first round of recycling is taken into account. This assumption is echoed in this report. In the baseline scenario, 32 per cent of glass is recycled, equal to 307 141 tons/year of recycled product. The share of recycled glass was increased to 100 per cent of product reintroduced as a recycled commodity. This had a positive impact on the economy overall, with a marginal increase in GDP of 0.01 per cent.

The increase in GDP growth, similar to the plastics waste stream, is mainly driven by an increase in private consumption demand. In the baseline scenario, 26 per cent of the glass produced domestically is consumed directly by households.

The price of glass decreases by 2 per cent as a result of the exogenous increase in the supply of recycled glass to the economy. Although this results in a decline in the intermediate use of glass by 0.1 per cent, this decline in the price has favourable trade outcomes as glass imports decline by 0.9 per cent and glass exports increase by 12.7 per cent.

The decrease in the price of glass does have a favourable impact on intermediate consumers as their production costs are lowered and profitability increased. These sectors include medical equipment; motor vehicles and parts; beverages and tobacco; and furniture.

There is a decrease in the gross value added (GVA) of the glass sector, as supply exceeds the demand for glass in the domestic and international market. This has a slightly negative impact on capital and labour demand from the glass sector, 0.57 per cent for both factors. The positive impact of lower glass prices on other sectors outweighs this negative impact on employment with 162 jobs created overall and due to supply constraints, an increase in the wage rate of skilled workers of 0.14 per cent.

4. Sensitivity Analysis

Sensitivity analysis was conducted on the model parameters, specifically trade elasticities, to assess whether these play a significant role in the model outcomes. The trade elasticities in SAGE are based on those used by the Industrial Development Corporation and estimated by van Heerden *et al.* (1997). Two scenarios were analysed where the substitutability of recycled commodities was increased and decreased by 20 per cent respectively. The results from the sensitivity analysis show no material difference to the outcomes presented in Section 3.2. The variation in real GDP is less than 0.001 percentage points; therefore marginal changes to the trade elasticities do not significantly influence the model results.

In our analysis, we assume that the supply of high skilled labour and capital is limited. This assumption reflects the labour market in South Africa, at least for the short to medium term (Bhorat *et al.*, 2002; Daniels, 2007). From the results we note that this constraint to growth drives up wages and returns to capital and limits the ability for companies to expand. As a sensitivity check we ease this assumption by allowing additional capital and labour to be attracted into the economy. An upward sloping supply curve is assumed for these factors of production. The results show that the marginal release in the constraint positively affects the expansion in real GDP growth. The ability to increase the supply of production factors would therefore enhance the impact of reintroducing recycled products into the economy.

5. Discussion

While this analysis does not account for the impacts of the recovery and recycling of waste streams, it highlights the potential that the reintroduction of recycled products may have on economic growth, FTE employment and welfare. Through economy-wide effects, an increase in the share of recycled products by 18 per cent has the potential to increase real GDP by 0.1 per cent and employ an additional 4 000 workers. If the target of 100 per cent of all waste recovered and recycled were achieved, real GDP could increase by 0.5 per cent and an additional 13 661 jobs could be created.

The analysis assumes a fixed capital and skilled labour supply. Results from the sensitivity analysis shows that if constraints to production are eased, the economic and employment impacts can be amplified as more resources are available for production.

This analysis could be greatly improved by the addition of recycling industries in order to include the potential job creation, enterprise development and macroeconomic impacts of value addition along waste stream value chains. By not including the addition of these recycling industries, it is likely that the economic impacts have been understated in this analysis.

There are also a number of social and environmental costs that are borne from the disposal of waste in landfills, including impacts on health, greenhouse gas emissions, soil and water contamination to name a few. By reintroducing waste as an economic commodity, these externalities can be potentially avoided or reduced (DST, 2014). It would be interesting to explore and account for these externalities in the 'true' cost of landfill waste and should be evaluated further in future work.

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