An economy-wide analysis of the circular economy potential in Germany – Enhancing product longevity and domestic recycling

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Abstract

Since the industrial revolution, our economic system has relied on resource exploitation and unsustainable treatment of waste. The circular economy provides an alternative method of producing and consuming commodities, which unites natural boundaries and economic goals. This study explores the potential of the German economy to advance towards a circular economy via the promotion of domestic recycling and repair services using a computable general equilibrium model calibrated to a 2018 social accounting matrix. In the first scenario, domestic recycling is promoted through a tariff of 80% levied on waste exports, using the additional revenue to subsidize the domestic recycling sector. In a second scenario, repair services are subsidized such that the consumer price falls by 50%. The subsidy is financed through an additional tax on the sale of machinery and equipment. The third scenario analyses the effects of regulations promoting the longevity and repairability of electronic products, machinery, and vehicles in industries, exogenously increasing intermediate demand for repair services by 50% and decreasing intermediate demand for electronic products, machinery, and vehicles accordingly. Preliminary findings indicate that a tariff on waste exports leads to a higher recycling rate, but also higher waste disposal costs. Decoupled economic growth is achieved as GDP grows slightly, while greenhouse gas emissions are reduced. The promotion of repair services and the reduced consumption of technical equipment and machinery leads to a shift in the domestic production structure. Capital-intensive industrial sectors shrink, while labour-intensive repair services expand, resulting in higher labour wages relative to capital prices and a reduced demand for energy and resources, which also results in a reduction of greenhouse-gas emissions. All scenarios result in higher self-sufficiency and a decreased reliance on imported resources, which can be seen as an additional advantage.

Keywords: decoupled growth, greenhouse gas emissions, longevity, recycling, planned obsolescence, extending lifetime

1 Introduction

Since the industrial revolution, our economic system has heavily relied on resource exploitation and unsustainable managing of waste. Yet, with finite resources and increasing problems caused by pollution, an alternate system of production and consumption is needed. The circular economy is such a system that aims at decupling of production from resource consumption aligning natural boundaries with economic goals. The main strategies for this are (1) increasing efficiency to reduce resource flow, (2) extending the longevity of products to slow resource flow and (3) recycling of materials to close the resource flow.

Against this background, this study aims to assess the economy-wide and environmental impacts of three policy measures currently under debate in Germany that promote the circular economy: reducing waste exports to other countries and an enhanced domestic recycling rate, and an increase of longevity of electrical equipment and machines a) through subsidizing repairs, and b) through regulations that promote reparability such as legislation mandating the ability to replace parts and prohibiting “planned obsolescence”. To the best of our knowledge this is the first study analysing the circular economy in Germany using a CGE model.

1.1 Circular Economy

The literature defines three basic strategies for the transition from the current economic system to a circular economy (Bocken et al. 2014): narrowing the resource flow, closing the resource flow, and slowing the resource flow (Figure 1).

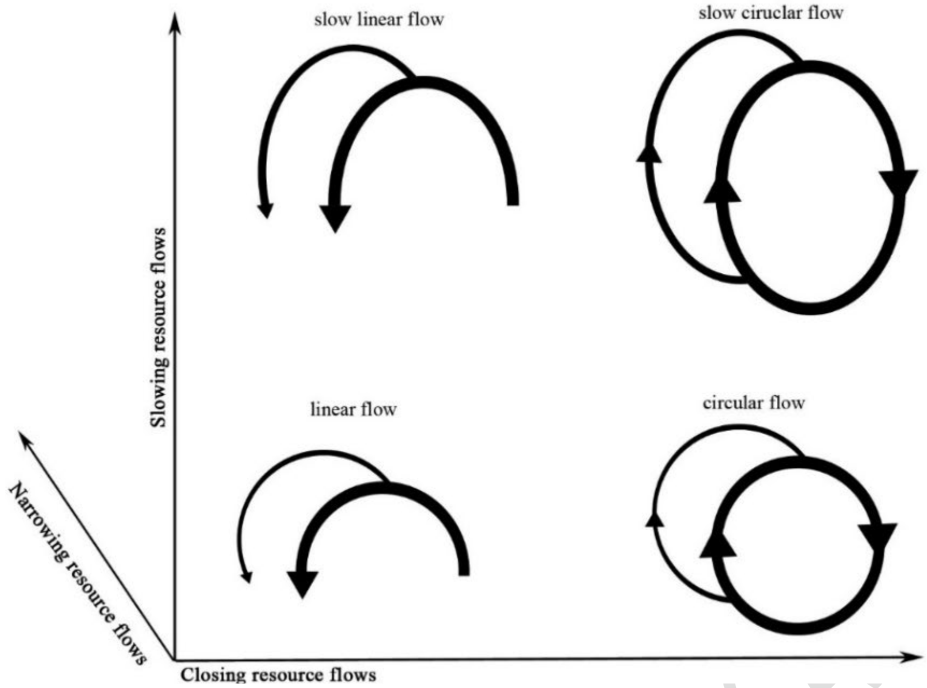

Figure 1: Three dimensions of the circular economy; Source: Bocken et al. 2014, p. 309

The three strategies have specific mechanisms to support the implementation of a circular economy. The slowing of the resource loop is achieved by extending the lifetime of the products via strategies of reuse, repair, and remanufacturing. The primary goal of this is to ensure that products are designed to be durable, the process of creating new products is slowed down, and products are in use for longer periods of time. Closing the resource loops bends the linear production curve. The primary mechanism of this strategy is material recycling, which contributes the creation of new goods. Waste is not considered a final product, as the materials are used to replace virgin materials, thereby closing the material flow. Narrowing the resource flow is an efficiency strategy designed to increase the output of products per unit input (Bocken et al. 2014)

The circular economy is also defined by the R-principles, which are similar to the transition strategies. To accomplish an ideal circular economy, three principles are applied: “reduce”, “reuse”, and “recycle”. Thereby, “recycle” means that the materials in a product have a secondary purpose, which will come into effect when the product is no longer suitable for further use. In the process, the same or lower material quality is optioned to create new goods. “Reuse” means that the lifetime of a product is expanded by utilisation by another consumer. “Reduce” is associated with better product use and improved product manufacture. Fewer resources are consumed in the creation of the goods and resources (Kirchherr et al. 2017).

1.2 Circular-economy development in Germany

Efforts to close resource flows in Germany are stagnating due to a standstill in recycling rates (Lutter et al. 2018). Rates have not increased since 2006, remaining at around 70% until 2019. At the same time, the disposal of waste has declined since 2006 and was replaced by thermal treatment (see Figure 2). This increase in thermal treatment was made possible by investments to decrease waste disposal by landfilling. The low cost of burning waste made this more economically attractive than recycling, which led to a deadlock in further recycling efforts (Wilts 2016).

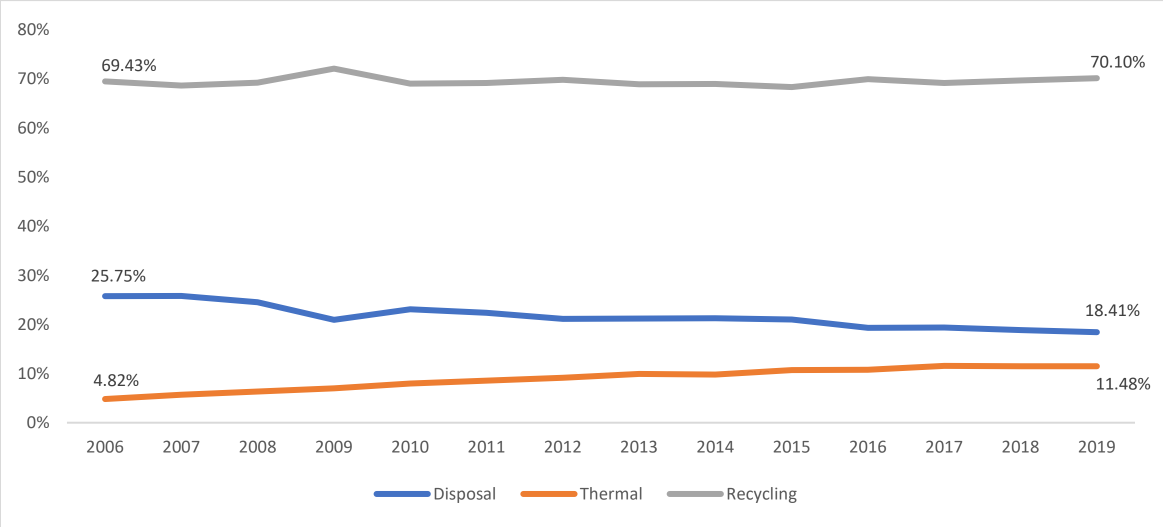

Figure 2: Waste use rates in Germany from 2006 – 2019; Source: Destatis 2022

The European Commission (2015) set a target for recycling of municipal waste by all member states of 60% in 2025 and 65% in 2030. National laws in Germany have increased recycling of municipal waste, setting a quota of 90% for metal, aluminium, glass, paper, cardboard, and carton; 80% for composite packaging; and 63% for plastics (Bundesregierung 2022b). According to Destatis (2020), the municipal waste-recycling quotas were met in 2012. In 2019, the recycling rate for household waste was almost 100% for glass, paper, cardboard, cartons, and electrical equipment. The overall recycling of municipal waste was 68% in the same year.

However, Obermeier and Lehmann (2019b) claim that the real recycling rates for municipal waste in Germany are lower than those published. In 2015, an official rate of 67% for municipal waste was declared, but estimates suggested that the true figure was between 36% and 40%. This deviation occurred due to the measurement including recovered material that was not used to replace virgin material. This input-based approach included waste from pre-treatment, sorting, and further distribution for purposes other than recycling (Obermeier and Lehmann 2019a). As a result, less secondary material was available for the private sector (Obermeier and Lehmann 2019b). The input-based and output-based recycling rates deviated by between 11% (for glass) and 73% (for street sweepings, non-biodegradable garden, and park waste). The input-oriented measurement suggested that 51–59% of all waste entering the waste management sector was not available as secondary material for further use (Obermeier and Lehmann 2019b).

The narrowing of the resource flow is depicted by the indicators of resource productivity and total resource productivity, which indicate how efficiently natural resources are being used in relation to economic performance. These resource indicators are also proxies for the environmentally friendliness of an economy, as reductions in the consumption of raw materials by mining, forestry, and agriculture sectors leads to less exploitation of natural resources (Umweltbundesamt 2022a). Resource productivity is measured as GDP relative to the direct material input (DMI)[1] of all abiotic material (BMUB 2016).

The narrowing of the resource flow can be achieved through the decoupling of GDP and resource consumption. Two forms of such a decoupling are possible. First, the resource use can increase at a slower pace as goods and services produced. This process is defined as "relative decoupling". "Absolute decoupling" is achieved when the two measurements diverge, with GDP increasing and resource consumption decreasing (International Resource Panel 2017). The 2002 German sustainability programme aimed at doubling resource productivity from 1994 to 2020. This goal was not fully reached, as productivity increased by 72% only (Umweltbundesamt 2022b). Yet, the development of resource productivity showed a successful absolute decoupling, with GDP and DMI diverging (Figure 3). The main driver of the absolute decoupling was the increase in imports. Between 1994 and 2014, more goods were imported, with metal products doubling and fossil fuels increasing by two-fifths (BMUB 2016).

[1] The direct material input measures all manufactured and consumed goods in an economy in tons per year. Included in the measurement are extracted domestic resources plus imports of raw materials, semi-finished and finished goods (BMUB 2016).

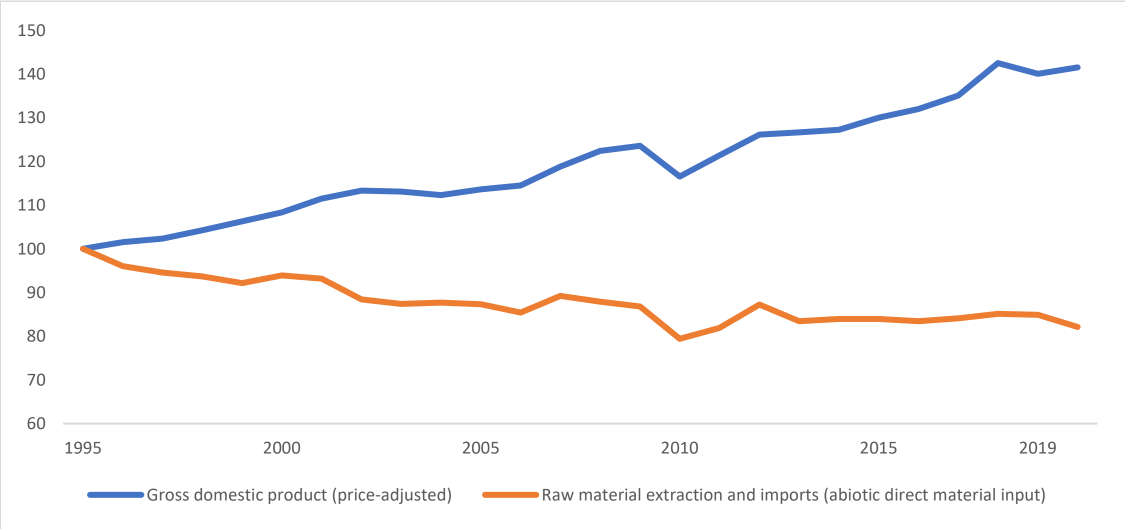

Figure 3: Resource productivity in Germany 1994 – 2019; Source: Umweltbundesamt 2022b

It has been possible to slow the resource flow in Germany by applying principles of share, reuse, refurbish, repair, and remanufacture. European Union indicators proved inadequate to assess the development of the slowdown. In particular, the R-strategies of reuse, refurbish, repair, and remanufacture were not well-depicted and required more coverage regarding data and assessment (Arnold et al. 2021). "Sharing" business models in Germany are prominent, with easy access via websites for the mobility sector (cars, scooters, bikes), accommodation (short-term stays), and daily-use items (local lending). However, assessments of the use of these services is vague due to a lack of accessible data. Car sharing is common in Germany, especially in rural areas, but the data on total usage are unclear. Daily-use items are only shared to a limited extent and represent a niche sector in the German economy, while the lending of private appartements is the most popular sharing market (BMWi 2018). The popularity of sharing (mobility items, clothes, books, and daily-use items) on the internet has shown that users are willing to lend their belongings to others. Furthermore, they were more likely to hire the same item compared to an interaction with an enterprise. Few of these platforms explicitly list the goals of the circular economy in their business models, but their intrinsic value belongs to the concept of the circular economy (Schwanholz and Leipold 2020). However, there was strong acceptance of only certain products. Most consumers say they cannot judge or do not trust the quality of the product, find the effort of searching to be too high, or lack information about the right platform to use (Wilts and Fecke 2020). Repair services are an important contributor to German craftsmanship. In 2014, approximately 6% of the revenue in the crafts sector was earned through the provision of repair services for cars, machinery metal products, other consumption goods (bikes and clothing), household goods, garden utilities, and electronical equipment. Repair services were predominantly provided by small businesses with up to four employees (Bizer et al. 2019). In 2014, 75% of all repairing businesses operated in the automotive sector, which generated the highest turnover. The second largest and second-most profitable sector was the repairing of machines. This sector accounted for 8% of all businesses in the market and had the second-highest turnover. Just 1% of all businesses working in the repair sector were involved in the repair of electrical equipment (Bizer et al. 2019). Of the products sold by 10 selected online platforms trading in refurbished products in Germany, half were categorised as electronic articles. The analysis included refurbished products that had been returned, B-products, and products with only damaged packaging. Most of the available refurbished products were smartphones and televisions (metoda GmbH 2022). Remanufacturing was prominent throughout the economy for B2B transactions. Germany accounted with the UK and Ireland, France, and Italy to the countries with the highest remanufacturing turnover. Together they remanufactured 70% value in the European Union. Germany took a leading role in the remanufacturing business with about one third of the European remanufacturing revenue (Parker et al. 2015). Remanufacturing in Germany is predominant in the aviation sector, followed by the car industry, and used with heavy trucks, electronics, and electrical equipment (Lange 2017).

1.3 Previous CGE studies of the circular economy

The literature on CGE models dealing with the circular economy is divided into models that are concerned with modelling waste and models that explicitly depict advancements of the circular economy. This literature review includes both types and is divided into four sections concerning the scenarios analysed (i.e.., narrowing, closing, and slowing the resource flow), while the fourth category includes hybrid studies that cover at least two of the mentioned approaches.

1.3.1 Narrowing the resource flow

Tuladhar et. al (2016) used a global CGE model to analyse circular economy policies in Denmark and the European Union. A circular activity was introduced in the model that included refurbishing, remanufacturing, or recycling through the input of waste. Efficiency improvements with conservative and ambitious goals were applied in 10 sectors. The results indicated that the GDP of the two regions increased, and the output prices of the sectors decreased. Winning et al. (2017) used a global CGE model which incorporated a high disaggregation of extraction, industry, and recycling, with a special focus on iron ore and steel. Doubling the secondary steel for treatment between 2018 and 2030 in each region increased secondary steel production by 7%. Global GDP increased and CO_2 emissions were reduced, largely due to a decrease in oil consumption. Peng et al. (2019) analysed efforts made towards a circular economy model, applying a CGE model that included an environmental satellite table and depicted different air pollutants. The first scenario examined the impact of a subsidy for remanufactured engines, the second an energy-efficiency increase of 15% in the Chinese engine-remanufacturing sector, and the third combined both scenarios. The analysis showed that the subsidy produced greater economic and environmental benefits than the energy-efficiency increase. Chateau and Mavroeidi (2020) used a global structural computable general equilibrium model to analyse policies for enhancing resource-efficiency and promoting a circular economy, with special focus on employment from 2018 to 2040. First, for all OECD and non-OECD countries, taxes were levied on metal and non-metallic mineral ores. Second, recycling was enhanced through subsidies and primary material consumption was reduced by a tax on primary materials. Third, the policies applied in the second scenario were applied in all OECD countries. The results for the first two scenarios indicated that employment decreased in countries with primary-material-extraction and material-intensive sectors and increased in secondary-material and recycling sectors. The third scenario decreased the competitiveness of the OECD countries and resulted in job losses. Bibas et al. (2021) used a dynamic computable general equilibrium model to analyse circular-economy policies in OECD countries, BRIICS, and the rest of the world for the period of 2017–2040. In the simulation, taxes were levied on primary materials, resulting in global reduction of demand. Relative decoupling of GDP and resource-consumption was observed. The reductions in material use were higher for BRIICS as a result of their intensive-resource-production structure.

1.3.2 Closing the resource flow

Miyata and Xiaojin (1999) developed a CGE model for Japan, using a waste-economic accounting matrix to analyse recycling scenarios. The scenarios investigated two material-recycling possibilities for Japan. The first scenario was the business-as-usual case, and the second analysed secondary-material substitution from waste to intermediate inputs for industry. The results showed that fewer minerals were extracted, due to the increase in recycled material. Higson (2013) used a dynamic global CGE model to investigate different types of taxation on landfill from municipal waste, construction, mineral waste, and discharge to water. Their findings indicated, for all scenarios, an almost unchanged GDP, as well as higher employment and higher consumer prices. Waste generation declined in all cases. Nechifor et al. (2020) used a dynamic global CGE model to investigate the potential of the circular-economy for Chinese steel recycling between 2019 and 2030. Three scenarios were implemented: first, an increase in scrap use of steel; second, an increase in scrap use of steel, paired with an increase in the capacity to use secondary steel; and third, improvements in steel-recycling practices. The results showed that iron-producing regions had the highest reductions in GDP, and the environmental gains from recycling were offset by an increase in coal consumption.

1.3.3 Slowing the resource flow

Brusselaers et al. (2021) used a CGE model to explore the prolonging of the lifetimes of household utilities and machines in Belgium. The authors implemented four scenarios: first, taxes were levied on environmentally unfriendly products and services; second, taxes were cut to encourage consumption of circular products; third, the first two scenarios were combined; and fourth, the first policy was implemented and tax was cut on all services. The results showed that these policies, contrary to the goals of the circular economy, did not lead to local job creation or import independence. Environmental benefits arose due to a reduction in emissions.

1.3.4 Hybrid studies

Honkatukia (2017) conducted a CGE analysis for Finland for the period of 2015 to 2030, investigating the seven potentials of the circular economy. Scenarios relating to agriculture concerned food-waste reduction, more efficient nutrient flows for fertilisers and biogas, an increase in fish fodder for agriculture, and a reduction in fertilisers. Further scenarios reviewed new recycling technologies and new transport solutions for consumers. The results showed that the transport scenario produced the largest increases in investment, employment, and GDP. Donati et al. (2020) used a standardised framework to assess circular-economy policies, using environmental-extended input-output tables to depict multiregional circular-economy policies. The model included circular-economy frameworks for resource-efficiency and product-life extension in the global economy. Their findings indicated decreases in all of the variables – namely, global warming, raw-material extraction, land use and blue water withdrawal, value added, and employment. The reductions were stronger for product-life extension than for resource-efficiency. Skelton et al. (2020) employed a recursive dynamic computable general equilibrium model to depict the relationships between the economy, energy systems, and the environment. It assessed policies for 28 European member states and for the OECD and G20 countries. Three scenarios were analysed: energy efficiency for steel, material efficiency for steel to manufacture cars, and product-service efficiency leading to a reduction in car demand. The results indicated that all scenarios reduced GHG emissions. Energy and material efficiency led to higher GDP and employment, whereas product-service efficiency led to a reduction in GDP and employment.

2 Database and Model

This study employs a single country computable general equilibrium (CGE) model (McDonald, 2007) which is calibrated to a, detailed SAM for Germany for the year of 2018, specifically developed for this study based on national accounts data and an input-output table provided by the German statistical office, Destatis (Elshof et al. 2022).

The SAM comprises of 160 accounts, including 63 economic activities, producing 85 commodity types and explicitly entails accounts relevant for the circular economy, such as waste and repair services. The additional agents are the government; one representative household, merged with the enterprises account; and the rest of the world. Taxes and contributions include trade and transport margins, taxes on products, social contributions, activity tax, and direct tax. Finally, stock changes and savings and investment are included. Satellite accounts are added to capture the greenhouse gas emissions of the different economic activities.

The nested production structure of the model is adjusted in order to depict the decision to either replace or repair broken machines, vehicles and electrical equipment in the production sector. This is achieved by including nests, allowing for the substitution between (service) commodities, namely repair services vs. aggregated equipment and machines.

2.1 Closures

Standard closures are applied for this analysis. We assume that Germany is a small country in all markets, which is why world markets are fixed. Also, foreign investments are assumed to be fixed such that the external account is balanced by adjustments of the exchange rate. Similarly, the government (dis-)savings are fixed, such that all welfare effects are realized in the current period. Also household saving rates are kept fixed such that investments are savings driven. To balance the government account, single tax rates are let to adjust endogenously as specified in the scenarios below, while all other tax rates are kept fixed. All factors are assumed to be mobile between sectors, such that this study takes a more long-term view. Finally, the CPI is the numeraire.

3 Simulations

As mentioned in section 1, there are several possible ways of enhancing the circular economy. In Germany, higher circular-material-use (CMU) rates can be achieved by decreasing the consumption of information and telecommunication devices and increasing rates of material recycling. The central mechanisms for enhancing reuse potential are the imposition of higher prices for new products and the facilitation of repair possibilities (Dittrich et al. 2021). These potentials are implemented in the following scenarios, which also consider vehicles and machinery.

3.1 Reducing waste exports (waste_exp)

The first scenario aims at enhancing the domestic recycling rate by taxing the export of waste. As economically the export of waste is an import of disposal and/or recycling services, in the model an import tariff of 80% is levied on these services. The tariff-revenue is then used to subsidize the domestic recycling sector.

3.2 Subsidizing repair services (repair)

In the second scenario the repair of equipment is promoted, through the introduction of a 50% subsidy on repair services, similar to the Austrian "repair-bonus", which has been introduced in 2022[2]. In the model this policy is financed through an endogenous increase of sales taxes on electronic products, machinery, and vehicles, such that it is cost-neutral to the government.

3.3 Enhancing lifetime of equipment (longevity)

The third scenario simulates a mandatory increase of longevity of machines, equipment and vehicles used in production by decreasing their consumption in all economic activities by 50% and instead increasing the demand for repair services by the same rate, following the approach of Donati et al. (2020). This is achieved by exogenously adjusting the input-output coefficients of activities.

4 Preliminary Results and Discussion

In the first scenario, aimed at promoting the closing of the resources-flow, waste exports reduce by 86%. However, despite of the domestic subsidy, this scenario results in higher waste disposal costs, while consumption of other goods largely remains constant. This may lead to an increase in illegal waste disposal. At the same time this scenario leads to a slight GDP-growth, due to an increase in domestic waste recycling, which also reduces the consumption of (non-recycled) plastic materials. The overall decrease in domestic greenhouse gas emissions from the production sector is minimal, at only -0.4%, as the expanding recycling sector is relatively energy intensive.

An increased demand for repair services and a reduced consumption of newly produced vehicles, machinery, and equipment, in scenario two and three, leads to a shift in the domestic production structure. Specifically, capital-intensive industrial sectors, such as car and machinery production, shrink, while labour-intensive repair services expand, resulting higher labour wages relative to capital prices. This trend tends to benefit lower-income households, who primarily earn income from labour. Additionally, as the production of machinery and vehicles is energy-intensive, these scenarios result in environmental benefits through a reduction of extractive activities and energy-consumption, which also results in a reduction of greenhouse-gas emissions.

[2] https://thestoriest.com/opinion/229859.html

In addition to promoting sustainability, each of the three scenarios results in increased self-sufficiency and a decrease in reliance on imported resources, which can be seen as an additional advantage, particularly during these times of global uncertainty and disruptions in trade.

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