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Macroeconomic impacts of African transport transitions: on the case of electric two-wheelers in Kenya

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ABSTRACT

The impact of the e-mobility transition on a national economy will depend strongly on that nation's set of fiscal policies regarding vehicle, fuel and electricity taxation. Here, we present a framework and online open-access tool to evaluate the macroeconomic impacts of vehicle electrification in any national context. By applying the framework to the booming electric two-wheeler sector in Kenya, we provide a set of context-specific recommendations regarding the impacts of transport electrification on Kenya's fiscal position, given a set of scenarios relating to vehicle market size and fiscal policy. It was found that in the Kenyan case, the e-mobility transition is unlikely to result in a significant black hole in government finances: for a given two-wheeler market size, it is predicted that the loss in revenue resulting from a business-as-usual shift to electric two-wheelers would result in the loss of only 3% of government revenue from the sector by 2040, totalling approx. KSh1.4bn (under 0.1% of Kenyan GDP in 2023). However, carbon taxation is a significant source of government revenue when applied to polluting technologies such as petrol-powered two-wheelers, potentially doubling the revenue returned from the Kenyan two-wheeler sector by the mid-2030s, relative to what it would be without carbon taxation, if IMF recommendations regarding carbon tax are followed. However, revenue from carbon taxation will dry up as the transition to e-mobility hastens. Of course, any intervention regarding taxation, including carbon tax, must be subject to careful policy analysis. Taxation policy should direct consumers towards desired behaviours (in this case, the uptake of electric over internal combustion-powered two-wheelers) and allow the redistribution of wealth to those most affected by transport poverty.

1. Introduction

The challenge of climate-forcing emissions mitigation is especially pertinent in the developing world, where economic and social progress must be balanced with environmental stability (Häyhä et al., 2016). Access to reliable transportation is crucial for fostering economic growth and socio-economic development. However, the traditional modes of transportation, mainly those reliant on fossil fuels, contribute significantly to environmental pollution and climate change (Ritchie et al., 2020).

Sub-Saharan Africa (SSA) is expected to see very high growth in transport demand over the coming decades. As an indication, transport emissions across the African continent grew by 84% between 2010 and 2016 (SLOCAT, 2018). However, it currently lags much of the world in infrastructure development, highlighting the significance of sustainable development patterns in the region (United Nations, 2008). Furthermore, the chronic lack of access to formalised public transport, private vehicles, or the infrastructure to support active travel in developing economies contributes to poor quality of life, particularly for vulnerable groups such as low-income earners (Gorman et al., 2019). Increasing access to transportation alongside the electrification of road vehicles has been widely touted as a fundamental tenet in sustainable transport-energy transitions for SSA. However, this transition will entail significant differences to economies' fiscal status quo due to shifts in taxation revenues amounting from markets of vehicles, fuels, and electricity.

Taking Kenya, a large African economy home to some of the world's fastest-growing cities and motorisation rates as a case study, this paper quantifies the macroeconomic impacts associated with the electrification of road vehicles in the motorised two-wheeler (2W) sector as a sustainable mode of transportation applicable to many other SSA

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countries. In doing so, the results of this study can be used in consideration of electric two-wheelers (E2Ws) and their potential to contribute towards sustainable development goals while addressing the pressing concerns of climate change, energy security, and social inclusivity.

The historical assumption is often that e-mobility is 'too advanced' for the African continent. However, recent studies have shown that e-mobility offers a chance for technology 'leapfrogging' in African countries, serving to increase transport access and improve both climate and public health outcomes (Abraham et al., 2021; Collett et al., 2021; Dixon et al., 2024). In the SSA context, Shell Foundation and McKinsey estimate that the annual sales of E2Ws by 2030 would increase in Kenya to 20–40% of the market share, with 135,000–315,000 E2Ws sold per annum (Shell Foundation, 2022). Comparably, in Nigeria, the market share of E2Ws by 2030 is assumed to be 5–15%, with a total E2W sales of 100,000–330,000 units annually.

There is, however, a notable research gap in the investigation of this transition on a nation's fiscal position. To address this gap, this paper presents a novel tool, the Macroeconomic and Total Cost of Ownership Reporting (MaTCOR) tool (Uzim, 2023), that can be used to investigate the macroeconomic impacts of the electrification of any vehicle segment given a background of particular fiscal policies in a given country. In this paper, we apply the MaTCOR tool to the case of E2Ws in Kenya.

2. On the macroeconomy of e-mobility transitions

Attention paid to the fiscal impacts of e-mobility transitions has been largely from high-income countries. For example, the Office for Budget Responsibility highlights that the percentage of electric vehicle (EV) sales in the UK has significant effects on government revenues, from fuel duty and vehicle excise duty (VED), as EVs do not pay either (Office for Budget Responsibility, 2021). In fact, rather than the 1.9% per year the estimate anticipates, fuel duty and VED receipts would be £0.5bn lower in 2025–2026 if the uptick in adoption rates in 2020–2021 indicated in the March 2021 prediction (3.8%) were to prevail over the next five years.

The higher adoption forecasts for Kenya are driven by its high electricity accessibility rate and high gasoline pump price that could nudge consumers towards E2Ws; in contrast, Nigeria's non-existing transport electrification goals indicate a slow EV adoption in its market. In the latter country, the prevailing low pump price of gasoline is primarily driven by government subsidies (Shell Foundation, 2022). However, the potential elimination of these subsidies due to the increased adoption of e-mobility holds the promise of substantial benefits to public finances, as the transition to E2Ws could reduce the financial burden from fuel subsidies while promoting a sustainable and cost-efficient transportation ecosystem (Trung and Urmee, 2024).

Subsection 2.1 provides an overview of the contribution of motorised two-wheelers to the Kenyan economy. Subsections 2.2 and 2.3 detail the available sources of revenue and necessary expenditures faced by SSA national governments as a result of the e-mobility transition.

2.1. Contribution to the Kenyan economy

The motorcycle taxi industry is a significant part of Kenya's economy. Isaac et al. described that "investments in *boda-boda* businesses as a source of income for residents in Kisumu West District has increased exponentially with a positive effect on local economic empowerment", including "most areas in Kenya" as well (Isaac et al., 2014). All signs indicate an accelerated increase in youths who have made several forays into this market opportunity. This increment should not be surprising given that there were 3800 motorcycles in Kenya in 2005 and over 120,000 in 2012 (Otieno, 2012). In 2008, Kenya removed import taxes on local motorcycles, which led to a boost in transport jobs and a 50% income rise for some youth using motorcycles as taxis. Isaac et al.'s, 2014 survey showed that 52.8% of riders earned KSh201-KSh500 (£1.15–£2.85) daily from the *boda-boda* business, 20.8% earned KSh501-KSh1,000, 13.9% over KSh1,000 (£5.70), and 12.5% earned KSh200 (£1.14) or less (Isaac et al., 2014).

Since most riders are paid according to daily performance, their daily pay varies according to the activities and performance of the day. Hence, these motorcycle taxi drivers provide 22 million daily trips, earning an average daily wage of about KSh700 ($3.99) (Autos Kenya, 2022). According to Autos Kenya, "the industry generates an estimated KSh357 billion (£2.03 billion) yearly, with drivers earning a cumulative of KSh980 million (£5.6 million) every day" (Autos Kenya, 2022).

Concerning importation, existing research suggests that "imports of motorcycles increased by 46.9% (109,260 units)" in one year (2021–2022) as Kenyans who had "lost their jobs due to the economic troubles of Covid-19 sought employment in the booming *boda-boda* industry" (Omondi, 2023). In 2021, the value of imported motorcycles was estimated at KSh20.8 billion, up 52.9% from KSh13.6 billion in 2020 (KNBS, 2022). When the excise duty on motorcycle imports was repealed in 2009 by the Kenyan government, Business Daily reports that "the number of motorcycles transported into the nation increased by a startling 207%" - 38,870 units in 2008 to 119,336 units (KNBS, 2022). But with the implementation of different tariffs, such as the reintroduction of the excise duty and the 16% value-added tax, "the number of imported motorcycles fell by just under 50%, from 340,697 in 2012 to 165,276 in 2013 (KNBS, 2022).

2.2. Revenue generation

Taxes and net social contributions are often the significant sources of income in SSA countries (OECD, 2021). For the case of the transport sector, especially within the African 2W market, government revenues are typically sourced from tax returns on imports, local assembly manufacturing, licensing and registrations, fuel sales, cost of labour, and value-added taxes (Gideon and Alouis, 2013).

2.2.1. Value-added tax (VAT)

Globally, 170 countries have implemented a VAT system that applies to the sale of goods (OECD, 2020). For Kenya, three (3) types of VAT rates apply to goods (National Treasury of Kenya, 2023):

- 0% - for zero-rated supplies. Goods listed in the 2nd Schedule to the VAT Act (e.g., the exportation of goods/services),
- 8% - for petroleum oils, motor spirits, and
- 16% - as a general rate for other goods and services.

2.2.2. Import duties

Governments in SSA impose import duties on 2Ws to protect domestic industries (assembly plants) and generate revenue. Import duties, typically calculated as a "percentage of the import value", serve as a "barrier to foreign competition and encourage local manufacturing" (Jet Worldwide, 2023). The revenue generated from import duties contributes to government funds and supports various economic initiatives. Based on the International Trade Administration's Commercial Guide, "a 25% import duty, a 2% railway construction charge and a 3.5% import declaration fee are applied to imported goods as determined by the Kenya Revenue Authority" (International Trade Administration, 2022; Kenya Revenue Authority, 2023).

Additional tariffs on imported motorcycle equipment, such as tyres and tubes, increase the revenue opportunities in Kenya. Table 1 outlines the different import duties applicable to Kenya.

2.2.3. Excise duty

Excise duties are indirect taxes that serve the dual purpose of revenue generation and regulating the usage of goods and services (Kumar and Prakash, 2020). The revenue generated from excise taxes can be allocated towards government programmes and initiatives. According to the Kenyan National Treasury, "tax expenditure on local assembly of motorcycles has been on the rise in Kenya since 2017" (The National

Table 1
Import duties and other applicable taxes to imported goods in Nigeria and Kenya (GRIPS, 2018; Kenya Revenue Authority, 2023; MOFCOM, 2014; Roam., 2023; Williams Deloitte, 2015).

Applicable Taxes		Kenya, July 2023
Import Duty	Completely Built-Up (CBU)	25%
	Semi-Knocked Down (SKD)[1]	–
	Completely Knocked Down (CKD)	0%
Value Added Tax		15%
Import Declaration Fees		3.5%
Railway Development Fees		2%

[1] In Kenya, the official distinction for motorcycle importation includes only CBU and CKD categories; there is no SKD.

Treasury and Economic Planning, 2022). This growth demonstrates that the government's financial incentive to boost the local assembly sector has resulted in industry growth. For locally assembled motorcycles, Kenya's treasury generated KSh3,019 m (£17.2 m) from excise duty tax expenditure in 2021 (The National Treasury and Economic Planning, 2022). Based on a legal report by the Kenya Subsidiary Legislation, a 2023 bill with tax exemptions for EVs, E2Ws, and batteries, along with a 15% corporate tax reduction for CKD and SKD, was signed by President Ruto (Roam., 2023).

2.2.4. Licensing and registration fees

Governments collect fees for licensing and registering of 2Ws, which vary across countries. These fees contribute to government revenue and are utilised for administrative purposes related to vehicle registration and monitoring (Edogbanya and Ja'afaru, 2013). In Kenya in 2022, the National Transport and Safety Authority (NTSA) launched new digital licence plates to "enhance the security features required to curb fraud cases such as motorcycle theft, logbook scams, and cases of terrorism" (Ombati, 2022). The government waived the cost of motorcycle registration and the new licence plate numbers to KSh1,500 and KSh1,550, respectively (Matara, 2023),(Njeri, 2023).

2.2.5. Fuel taxes

Governments often levy taxes on fuel sales, and a portion of these taxes can be attributed to 2Ws. After doubling petroleum VAT to 16% in 2023, Kenya's fuel taxes have risen to one of the highest in Africa (Seban, 2023). According to the Business Daily newspaper, "taxes contribute to 40% of the cost per litre of fuel in the country". In Kenya, every litre of petrol generates KSh62.89 in tax revenue, a 39% increase over the previous two years, making the Kenya Revenue Authority (KRA) a significant gainer from the spike in pump prices (John, 2022a). In June 2020, the KRA collected KSh45.1/l in taxes and levies from petrol, compared to KSh51.6/l the previous year.

2.3. Expenditure

2.3.1. Fuel subsidies

According to consumption data from the Energy and Petroleum Regulatory Authority (EPRA), Kenya paid KSh11.86bn per month to maintain gasoline prices down for the six months leading up to June 2022. Diesel received the most significant portion of the subsidy over the six months (KSh45.7bn), followed by petrol (KSh23.3bn) and kerosene (KSh1.9bn) (Eunniah, 2022). KSh20.4 is subsidising petrol per litre, diesel by KSh27.6 per litre, and kerosene by KSh26.9 per litre during the April 2022 price hike (John, 2022b). Since the beginning of 2022, a rise in Brent prices has strained government coffers due to the rise in compensation margins for oil dealers who try to keep pump prices low. As a result, the government partially removed the subsidy, which raised the price of a litre of super and diesel in Nairobi to KSh150 (John, 2022b). Table 2 illustrates the breakdown of fuel prices per litre in Kenya as of 2022.

Table 2
Price breakdown of petrol and diesel costs in Kenya (John, 2022b).

Description	Petrol (KSh/Litre)	Diesel (KSh/Litre)
Product costs	97	106
Distribution & Storage	3	3
Margins	0	0
Price stabilisation	−12	−28
Taxes & Levies	62	50
Total	**150**	**131**

3. Methodology

3.1. Transport macroeconomic framework (TMF)

In this study, we propose a transport macroeconomic framework (TMF) to capture the various key drivers that affect the adoption of E2Ws, for both a generic internal combustion engine-powered two-wheeler (ICE-2W) and an E2W alternative. Factors such as the total share of 2Ws, vehicle and associated subsystem cost (e.g. batteries) and accrued taxes applicable to goods and services were reviewed. Macro-level inputs such as import duties, excise duties on local manufacturing, vehicle fuel economy, fuel pricing, and associated emission intensity were analysed to determine the market prospects for 2W electrification. An overview of this methodology can be seen in Fig. 1.

3.2. Scope of this paper

We are only considering the fiscal impact within the sale of vehicles and the liquid fuel or electricity that provides the energy for their motion. We hereby acknowledge that there is a wider set of parameters within the supply chains of the vehicles and energy sources, including electricity infrastructure, roads, manufacturing, maintenance and decommissioning. Taxation revenues otherwise in the supply chain, including taxes on fuel for energy generation, taxes on equipment for infrastructure, and taxes on importing concrete for building roads, are not presently considered in the framework; the addition of these elements into the framework, however, is eminently possible and recommended for future work.

3.3. Data

The literature review in section 2 determined the fiscal parameters that significantly influence the acquisitions of clean transport technologies in developing countries; hence, these data are collected from different sources. Top-down data include foreign trade statistics, passenger vehicle segmentation, annual revenue performance reports, and vehicle registration records in .csv formats. In contrast, bottom-up data include household data on energy consumption and business-level operations data in tabular format, sourced from AfEMA's electricity tariff review for Kenya (Ondanje and Giki, 2023), which are available for research use.

Stakeholder interviews with e-mobility companies in the region were sought to build on and validate the data gathered through literature, which is identifiably scarce within the African e-mobility scope. One-on-one interviews were conducted with three business leaders in the Kenyan E2W businesses and experts within the electric mobility market. These interviews provided in-depth insights into the companies' business models, strategies for promoting E2Ws, obstacles encountered, and factors influencing their success.

A summary of all collected datasets can be seen in Table 3, with brief descriptions of their characteristics and sources.

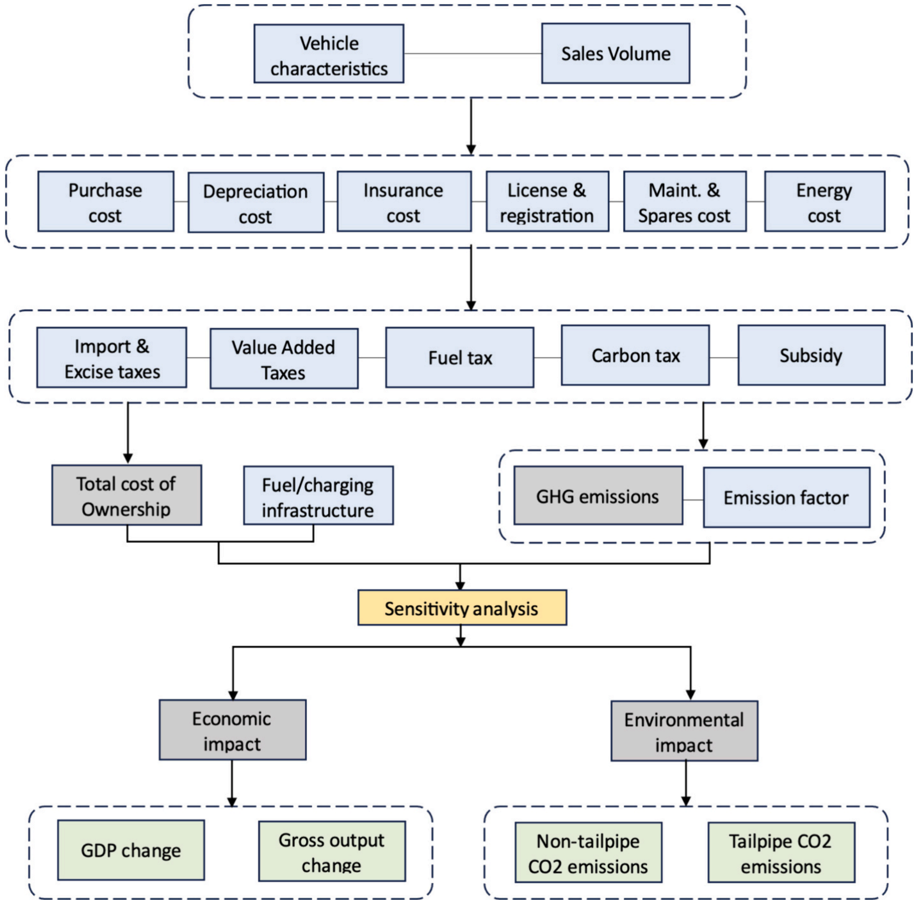

Fig. 1. Flowchart showing methodology of Transport Macroeconomic Framework (TMF).

3.4. Model

A mathematical model of macroeconomic impact from 2W electrification was developed to account for financial flows susceptible to variation based on the presence of either internal combustion engines or electric propulsion systems. The model described in this section is used to explore changes in macroeconomic impacts affected by varying socio-political scenarios (see section 3.5). The complete cost of the 2W operation from the point of acquisition onward was evaluated using the formulated approach in (1).

$$C = C_{2W} + C_M + C_S + C_F + C_T + C_{Imd} + C_{Exd} \quad (1)$$

where C_{2W} – 2W purchase expenses,
C_M – cost of maintenance,
C_S – cost of spare parts for repairs,
C_F – cost of fuel,
C_T – 2W on-the-road cost such as taxes and other payments,
C_{Imd} – incurred import duty/tariff cost,
C_{Exd} – excise duty cost.
Furthermore, the purchase expenses were calculated using (2).

$$C_{2W} = C_{vc} + C_{reg} \quad (2)$$

where C_{VC} – 2 W cost after OEM margin,
C_{Reg} – 2 W licence and registration cost.
Computation for maintenance, spare parts, and fuel costs are outlined according to (3)–(5).

$$C_M = C_{M-RD} + C_{M-L} \quad (3)$$

$$C_S = C_{S-RD} + C_{S-L} \quad (4)$$

$$C_F = C_{D-1l} \times Q \quad (5)$$

where $C_{M\text{-}RD}$ – spare parts cost used in maintenance,
$C_{M\text{-}L}$ – maintenance labour cost,
$C_{S\text{-}RD}$ – spare parts cost used in repairs,
$C_{S\text{-}L}$ – labour cost on 2W repairs,
$C_{D\text{-}1l}$ – cost of buying a litre of gasoline/ kWh of electricity,
Q – annual energy consumption.
On-the-road costs are calculated according to (6).

$$C_T = n \times T_C \quad (6)$$

where n – total operational lifetime of 2 W, T_C – annual payments such as insurance and road tax.

3.4.1. Annual distance of travel

The analysis considers an annual minimum travel distance of around 17,808 km for both ICE-2Ws and E2Ws, as identified by the TrIGGER report (GIZ, 2019). However, McKinsey's electric transport transition report suggests a maximum of 120 km per day for a high mobility case. Commercially-used 2Ws are the predominant mode of paratransit transportation, with 80% of these 2Ws being used as taxis or for last-mile delivery services in SSA (FIA Foundation, 2022).

3.4.2. Ownership and lifetime of 2Ws in SSA

Various factors, including driving behaviour, road conditions, vehicle characteristics, traffic situations, operational circumstances, and maintenance practices influence the lifespan of two-wheelers. A study conducted by the University of Nairobi revealed that motorcycles of engine sizes between 150 cc to 250 cc have a median life expectancy of 9 years (Notter et al., 2018). On average, 2Ws globally are assumed to

Table 3
Data sources used for study.

Variable	Description	Reference
Vehicle price – ICE-2 W	Price for a generic 150 cc petrol-powered motorcycle.	(The Star, 2023)
Vehicle price – E2W	Price of Roam Air electric motorcycle.	(Musalia Wycliffe, 2023)
Battery price	Latest estimate of $150/kWh scaled up to $200/kWh (Bloomberg New Energy Finance).	(Musalia Wycliffe, 2023)(Baker, 2022)
E2W without battery	Reported purchase price reduction of 40% for an E2W without battery (Energy4Impact).	(Energy4Impact, 2023)
Motorcycle component cost	Annual imports of motorcycle spare parts from National Bureau of Statistics 2022.	(KNBS, 2022)
Maintenance costs	Cost comparison for both ICE-2 W and E2W maintenance (Ecobodaa).	(Remeredzai, 2020)
Margin - Automaker OEM	Estimated OEM marginal cost - International Council on Clean Transportation (ICCT).	(Rokadiya, 2024)
Margin - Retail Dealer	Retail margin on showroom price (ICCT).	(Rokadiya, 2024)
Fuel price - Petrol/Diesel	Round estimate of prices across Kenya (GlobalPetrolPrices.com).	(GlobalPetrolPrice, 2023)
Fuel price - Electricity	Africa *E*-Mobility Alliance (AFEMA) states KSh22/kWh as e-mobility tariff & KSh32/kWh as base rate (including taxes).	(Ondanje and Giki, 2023)
Fuel economy – E2W	AfEMA reports 4 kWh/100 km for E2Ws.	(Ondanje and Giki, 2023)
Fuel economy – ICE-2 W	AfEMA suggests a rate of 3.74 L/100 km.	(Ondanje and Giki, 2023)
Tax - VAT	VAT rates applicable to goods in Kenya.	(FIRS, 2024; Kenya Revenue Authority, 2023)
Licence and Registration	Licence rates and motorcycle registration for the different countries.	(Adepegba, 2021; Ayodele, 2021; Matara, 2023; Njeri, 2023)
Tax - Central Excise and customs duties	Excise duties and import tariffs, including exemptions for local E2W manufacturing.	(GRIPS, 2018; Izuaka, 2023; MOFCOM, 2014; Roam., 2023; Williams Deloitte, 2015)
Tax – Fuel Tax	Current listed fuel taxes applicable to ICE-2W.	(Anyaogu and Oladipo, 2023; PwC, 2023; Seban, 2023)
Import tariff - battery	Import exemption on batteries in Kenya.	(Roam., 2023)
Import tariff - spare parts	Import taxes applicable to spares import.	(KNBS, 2022)
Carbon intensity – Grid Electricity	The carbon intensity of electricity in Kenya measured 116 gCO_2/kWh.	(Laconde, 2018)
Carbon intensity – Petrol and Diesel	BP Target Neutral - Global online travel calculator.	(BP, 2024)
Carbon intensity – For Battery Cell Manufacturing	100 kgCO2e/kWh reported & assumed 5000 cycle life (World Electric Vehicle Journal).	(König et al., 2021)
Carbon intensity – Petrol and Diesel	As reported on the website Dieselnet.com	(DieselNet, 2024)

have an age of 4–5 years (Dung et al., 2015). For the purpose of this report, a conservative estimate of a 9-year lifespan for 2Ws is assumed, and this value is utilised to define the 9-year ownership period for the total cost of ownership calculation.

3.5. Policy scenario development

In this study, three distinct policy scenarios are used to explore the impact of different trajectories for E2W adoption in sub-Saharan Africa. These are detailed in Table 4. Table 5 outlines the associated policies and tariffs utilised in the analysis. 2040 is used as the end year in all scenarios to be aligned with Kenya's national policy ambitions as outlined in the Kenya Energy Transition & Investment Plan (Ministry of Energy and Petroleum, 2023), in which it is projected that electric motorcycles will see rapid adoption and become the dominant mode of transportation in the two-wheeler segment by 2040.

3.6. Market size forecasting

To conduct the macroeconomic analysis in this study, the market size of ICE-2 Ws and E2Ws in Kenya had to be forecasted. To do this, historical annual sales of 2Ws were taken from the Kenyan Statistical Abstract (Kenya National Bureau of Statistics, 2022) and used as data points on which to fit a quadratic 2 W market size curve. Under this forecast, the market size of 2Ws increases from approx. 200,000 units in 2023 to approx. 540,000 units by 2040. For the Slow Lane scenario, 0% uptake of E2Ws is assumed. Under the BaU scenario, the same overall market size is considered, but the proportion of sales that are E2Ws raises from 1% in 2023 to 51% in 2040. Under the Green Growth scenario, the prevalence of E2Ws and reductions in motoring costs for those E2Ws leads to a higher overall 2 W market. Thus, the 2 W market increases to 675,000 units per year by 2040: by the same year, 74% of

Table 4
Scenario descriptions for macroeconomic impact analysis.

Scenario	Description
Slow Lane	This scenario represents one where E2W adoption is stunted, and ICE-2 Ws remain the prevailing choice. Within this scenario, the market environment is characterised by circumstances aligned with the current state of affairs, and the uptake of E2Ws is limited to practically zero driven by a widespread lack of charging infrastructure, product unavailability and a lack of consumer awareness. Unlike more interventionist scenarios, no notable regulatory impetus prompts a shift towards E2Ws.
BaU	This scenario primarily hinges on existing market conditions in SSA. It assumes limited regulatory interventions to drive the E2W transition. Instead, E2W adoption is influenced by factors such as affordability and availability. The 2W sector, predominantly comprised of used motorcycles, does not experience a significant transition until post-2035, when an ample supply of used E2Ws becomes accessible, allowing them to compete with used ICE-2Ws in terms of cost-effectiveness. Corporate-owned fleets, constituting around half of all 2Ws, are projected to transition to E2Ws more swiftly due to companies' sustainability goals and the operational cost advantages of electrified vehicles. The E2W segment, already displaying momentum, is expected to mirror trends observed in Asia. This scenario also considers each country's existing electricity reliability challenges (e.g., Nigeria's low reliability leading to lower adoption rates) while assuming ongoing investments to enhance reliability over time. The analysis underscores that 2Ws will embrace electrification slowly, with projected predictions to reach 50% of total sales by 2040, according to McKinsey's electric transport estimation for SSA (Conzade et al., 2022).
Green Growth	This scenario envisions an EV market that is actively shaped by stakeholders through various interventions. Governments establish regulations and incentives, as seen in Norway, where 75% of long-distance buses must be emission-free by 2030 (Symons, 2022). These strategies include bans on internal combustion engine vehicle sales and tax exemptions for EVs. These measures expedite the adoption of more locally manufactured E2W, potentially exerting a stronger influence on vehicle ownership, where owners are particularly cost-conscious and more likely to encounter targeted incentives or regulations (e.g., mandates for a carbon tax on ICE-2W fuel consumption). The analysis highlights that the transition towards electrification will occur more rapidly within the 2W segment. Projections indicate that electric two-wheeler sales are anticipated to surpass 70% of the total 2W sales by 2040 (Conzade et al., 2022). Moreso, it incorporates a carbon tax in line with the $6/tCO2eq recommended by the International Monetary Fund (IMF) for emerging economies (Parry et al., 2021).

Table 5
Policy assumptions for scenario analysis on E2W adoption in Kenya.

Scenario	Import tariff	Excise duties	VAT	*E*-mobility electricity tariff/kWh	Carbon tax
Slow Lane	25%	10%	16%	–	–
BAU	25%	10%	16%	KSh20.97	–
Green Growth	0%	0%	0%	KSh16.00	\$6/tCO_{2eq} in 2023, increasing to \$30/tCO_{2eq} by 2030 and continuing at the same compound increase to 2040

them are forecasted to be E2Ws. The forecast market size for ICE-2 Ws and E2Ws for all scenarios is shown in Fig. 2.

4. Results

4.1. Slow lane

Using the baseline ICE-2W scenario, it was essential to understand the government expenditures and income unique to the scenario. The results were categorised into **11** observations enveloped into **5** major groups (‘*import tariffs*’, ‘*excise duties*’, ‘*taxes*’, ‘*licence and registration*’, and ‘*subsidies*’), captured in Fig. 4. Total revenues are shown to total KSh31.0 billion (£169.9 million) in 2030. This value is majorly attributed to the 89% (KSh27.7 billion) from taxes, whereas ‘*import tariff*’ and ‘*excise duty*’ only had a combined share of 7.7% (KSh2.4 billion) from Fig. 3. Conversely, ‘*subsidy*’ expenditure on gasoline was not left out as it accounted for a government spending of KSh5.9 billion (£32.4 million). From Table 6, taxes and subsidies were the prominent players with significant fiscal impact on the public funds. The most significant analysis was ascertaining the final public purse balance from the total income and expenditure. Hence, a ‘*net balance*’ analysis for Kenya would suggest a final government balance of KSh25.1 billion (£137.6 million) and KSh45.0 billion (£246.5 million) in 2030 and 2040, respectively.

4.2. Business-as-usual (BaU)

A deeper dive into Fig. 5 and Fig. 6 presented a cross-section of government revenue and expenditures, with a significant increment for ‘*tax*’, ‘*excise duty*’, and ‘*import tariff*’ from E2W sales. Total ‘*excise duties*’ were observed to have improved by 67% (KSh0.3 billion), while “*taxes*” declined the most by 5% (KSh2.5 billion). Due to the predicted 2W electrification, the net public balance averaged KSh43.6 billion (£239.3 million) in 2040 – a decrease of 3% from the base case scenario for ICE-2W (shown in Table 7).

4.3. Green growth adoption

According to the “Laffer Curve” relationship analysed by (Prinn et al., 2017), carbon taxation offers a dependable source of revenue to finance government fiscal initiatives. Therefore, carbon taxes were employed better to understand the magnitude of impact for the accelerated case. Considering all the variables from the earlier analysis, the revenue from carbon taxation resulted in an income of KSh0.8 billion (at \$6/tCO_{2eq} in 2023) and increase to KSh7.3 billion (at \$30/tCO_{2eq} by 2030, according to IMF). By 2040, the carbon tax bolstered a significant increase in the final net balance to KSh85.5 billion (£469.4 million) - greater than the BAU scenario by 96%. Fig. 7 and Fig. 8 provide a trend of growing net balance values between 2023 and 2040 for the accelerated scenario.

5. Discussion

This section discusses the results of the key metrics linked to E2W prioritisation, the trends in the correlation between government revenues and expenditures, and the crucial parameters derived from various analyses using the macroeconomic model. The MaTCOR tool (Uzim, 2023) is made available for use and promoted as open-source and submitted as part of this paper.

Fig. 9 provides a comparison between scenarios. It is shown that the Slow Lane and BaU scenarios exhibit similar net public balances within the first 12 years. However, from the early-mid 2030s, the ‘Slow Lane’ is observed to exceed the BaU, increasing with a difference of KSh0.1bn to KSh1.4bn between 2030 and 2040. As the market size remains the same, this difference is due to the difference in fiscal policy (accounting for taxation and subsidy) applied to petrol and electricity. Due to the forecasted increase in the market size of 2Ws, both scenarios see a growth in

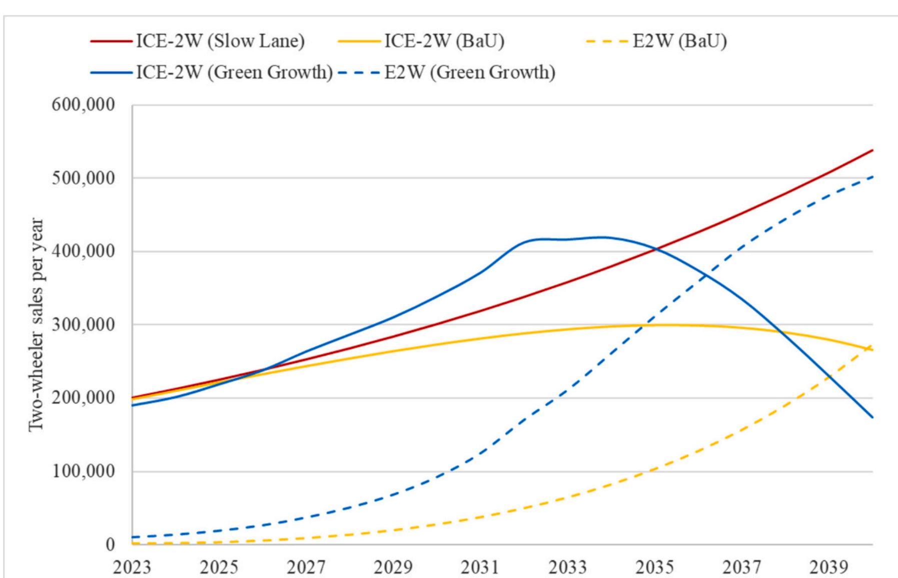

Fig. 2. Forecast vehicle sales for Kenya and powertrain breakdown by scenario, 2023–2040.

Fig. 3. Annual income and expenditure trend for Slow Lane scenario between 2023 and 2040.

Table 6
Incomes and expenditures for key intervals for Slow Lane scenario broken down into category, 2023–2040.

Fiscal variable	Macroeconomic impact (KSh bn)				
Import tariffs	**2023**	**2025**	**2030**	**2035**	**2040**
Import tariff – ICE-2 Ws	1.1	1.2	1.7	2.2	3.0
Import tariff – Spare parts	0.1	0.1	0.1	0.2	0.3
Total (imports revenue)	1.2	1.3	1.8	2.4	3.2
Excise duties					
Excise duty - Vehicles	0.4	0.4	0.5	0.7	1.0
Excise duty - Spare parts	0.0	0.0	0.0	0.1	0.1
Total (excise duties)	0.4	0.4	0.6	0.8	1.1
Taxes					
Tax – VAT ICE-2 W Sales	5.1	5.8	7.7	10.4	13.9
Tax – VAT Fuel Sales	10.3	11.6	15.5	20.7	27.7
Tax – VAT Maintenance	1.7	1.9	2.5	3.3	4.4
Tax – VAT Spare part sales	1.1	1.2	1.7	2.2	3.0
Tax - Insurance Cover	0.2	0.3	0.4	0.5	0.6
Total (tax)	18.4	20.7	27.7	37.1	49.6
Other variables					
Licence and Registration	0.6	0.7	0.9	1.2	1.6
Subsidy on fuel sales	−3.9	−4.4	−5.9	−7.9	−10.6
Total revenue	20.6	23.2	31.0	41.5	55.6
Total expenditure	−3.9	−4.4	−5.9	−7.9	−10.6
Net Balance	**16.7**	**18.8**	**25.1**	**33.6**	**45.0**

net government revenue. Whilst the move to E2Ws in the BaU scenario results in some loss of revenue from the government, taxation on electricity means that this is relatively small: in 2040, the lost revenue from the e-mobility transition accounts for KSh1.4bn, approx. 3% of government revenue from the sector. The net revenue from the sector under the Green Growth scenario is predicted to increase significantly to KSh95.8bn in 2037, representing a doubling of government income from the sector versus the Slow Lane and BaU scenarios. However, a steady 10% decline is predicted between 2037 and 2040 due to the decreasing share of ICE-2 Ws and thus the loss of carbon tax income.

The incorporation of the IMF-recommended carbon tax proves to be a significant contributor to the net balance of government revenue in the Green Growth scenario. Increasing from KSh0.8bn in 2023 to KSh7.3bn by 2030 shows the potential of carbon taxation as a substantive revenue generator. By 2040, the carbon tax will push the net balance significantly higher, reinforcing the relevance of environmental fiscal policies in shaping a country's economic trajectory. However, it is crucial to contextualise the "Laffer Curve" relationship in Fig. 9, suggesting that increasing tax rates may not necessarily yield higher tax revenues beyond a certain point. This interplay between tax rates and total tax revenue ensures that governments maintain an equilibrium, balancing environmental objectives with economic imperatives.

This analysis begs the question: will the revenue from carbon taxation remain robust as more entities transition to green technologies and thus produce fewer emissions? Initially, when carbon taxes are introduced, they target a broad range of carbon-intensive industries and activities. This carbon taxation creates a significant revenue stream for governments. The funds are often reinvested in sustainable infrastructure and research or sometimes returned to citizens as dividends or tax cuts. Emissions will decrease as entities shift towards green technologies to avoid the tax. This emission decline is the desired outcome, but it also means that the revenue from the carbon tax will decrease over time. This outcome potentially leaves a void in governmental revenues if they have come to rely on this source and could be mitigated by decoupling economic growth from carbon emissions, as observed from Sweden's economic growth by more than 60% from 1990 to 2017 after the introduction of a carbon tax in 1991 (Andersson, 2015).

On this note, it is essential to appreciate the multifaceted role of taxation. Beyond merely generating revenue, taxation also plays a pivotal role in wealth distribution and discouraging undesirable behaviours (like taxes on alcohol or cigarettes) (Kelton, 2021). Carbon taxation exemplifies this such that penalising the transportation sector with heavy carbon footprints indirectly promotes a shift towards greener technologies. The wealth generated from this can be directed towards benefitting the larger populace, especially most Kenyans with minimal emissions. Furthermore, considering the rising concerns of air pollution in SSA cities, the tax is a deterrent against transport technologies contributing to this grave issue.

6. Conclusion and further work

This paper has presented a framework and tool for the assessment of the macroeconomic impact of the e-mobility transition in the context of SSA nations. Through the application of the framework to the E2W transition in Kenya, we have demonstrated the tool's ability to evaluate the changing fiscal position of government revenue and expenditure following the uptake of E2Ws in a variety of policy contexts. It can be concluded that:

1. In the Kenyan case, the e-mobility transition is unlikely to result in a significant black hole in government finances; for a given 2W market size, it is predicted that the loss in revenue resulting from the forecasted BaU shift to E2Ws would result in the loss of 3% of

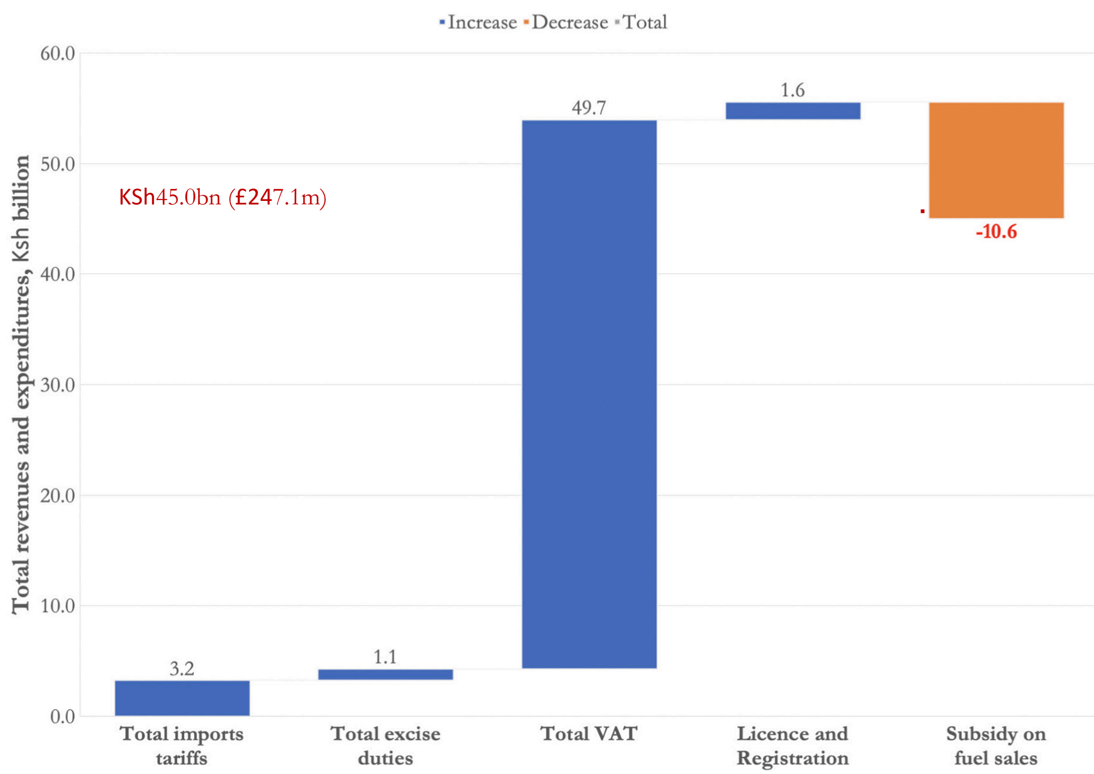

Fig. 4. Forecasted fiscal position for Kenya's Slow Lane 2040.

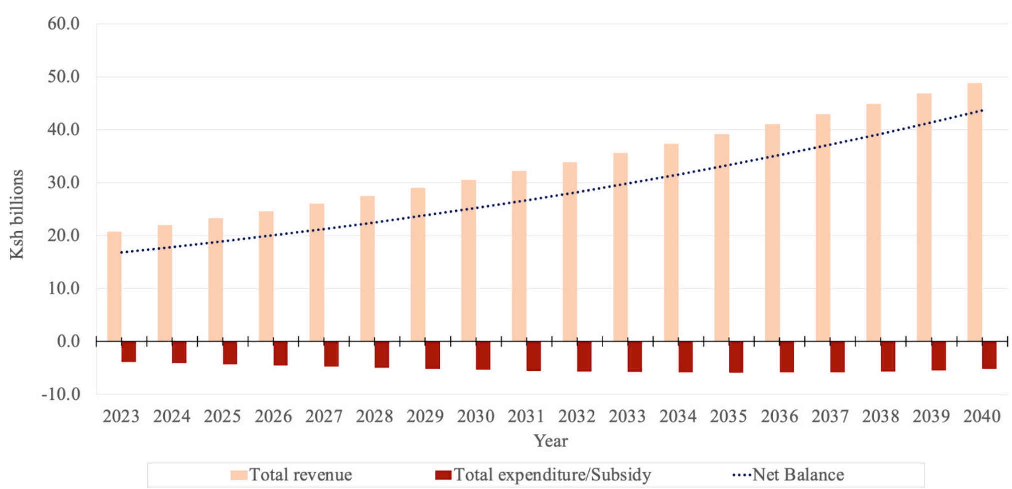

Fig. 5. Annual income and expenditure trend for BaU scenario between 2023 and 2040.

government revenue from the 2W sector, totalling approx. KSh1.4bn (under 0.1% of Kenyan GDP in 2023).

2. Carbon taxation is a significant source of government revenue when applied to polluting technologies such as ICE-2Ws, potentially doubling the revenue returned from the Kenyan 2W sector by the mid-2030s if IMF recommendations regarding carbon tax are followed. However, revenue from carbon taxation will dry up as the transition to e-mobility hastens.
3. Any intervention regarding taxation, including carbon tax, must be subject to careful policy analysis. Taxation policy must be progressive; it must direct consumers towards desired behaviours (uptake of E2Ws over ICE-2Ws) and allows the redistribution of wealth to those most affected by transport poverty.

Given the projected surge in the adoption of E2Ws in Kenya and its associated implications on the Kenyan job market and economy, there is an urgent need for proactive transition policies. Such strategies are imperative in ensuring that while the nation transitions to a greener transportation future, no segment of society is disproportionately affected or left behind. Some of these transition policies include:

1. Comprehensive Skill Training and Reskilling: As the reliance on fossil fuels wanes, it is crucial that the workforce is equipped with skills suited for emerging industries. Comprehensive training programmes focusing on E2W manufacturing, battery technology, and renewable energy infrastructure will be pivotal. Social safety nets need to be provided for workers who face unemployment during the transition to ensure they have access to unemployment benefits, retraining

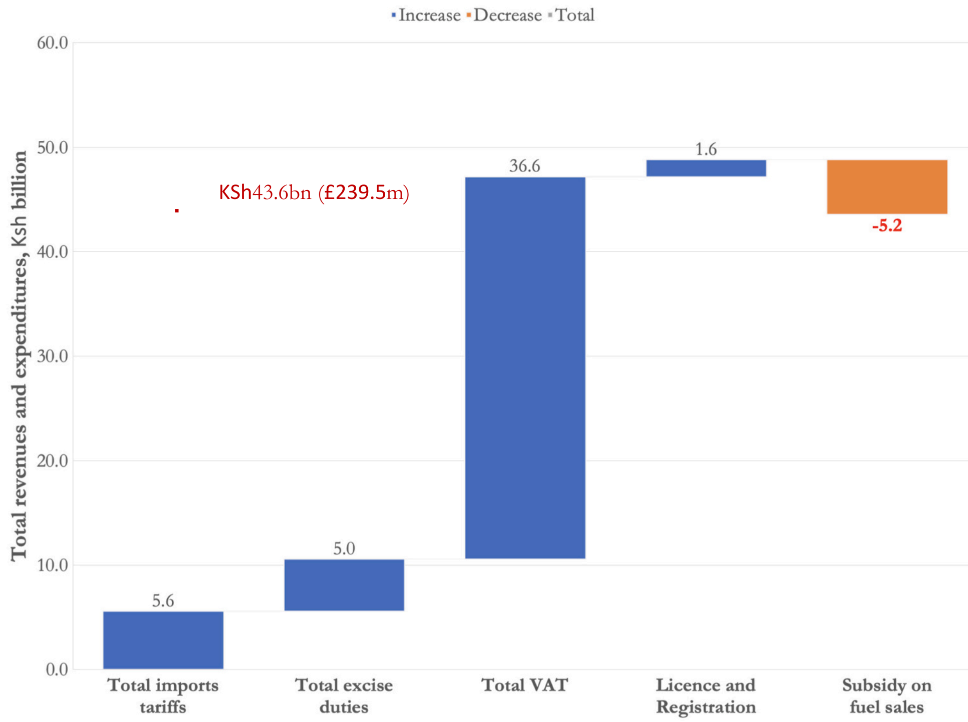

Fig. 6. Forecasted fiscal position for Kenya's BaU scenario 2040.

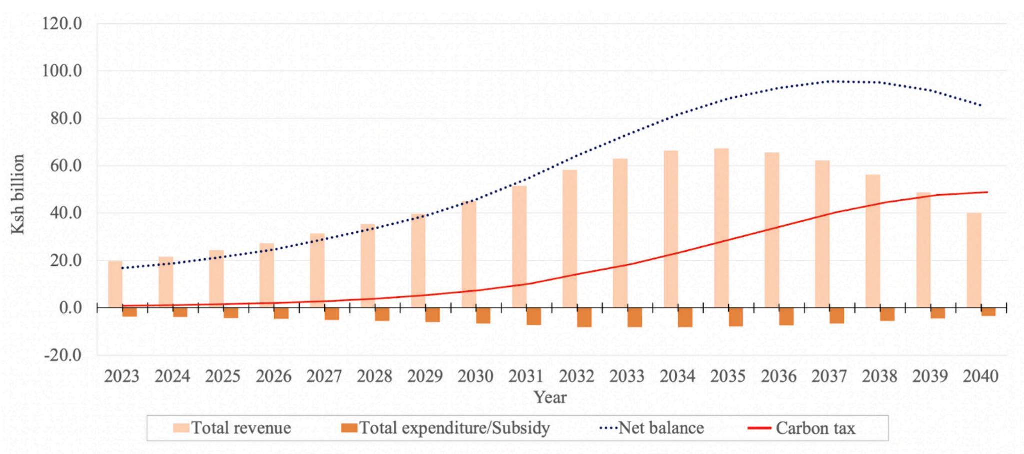

Fig. 7. Annual income and expenditure trend for Green Growth scenario between 2023 and 2040. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

programmes, and job placement services. This strategy can help in alleviating the short-term economic hardships they may encounter.

2. Support for Affected Industries: Industries and workers heavily invested in the traditional ICE-2Ws and fuel sales will be hardest hit. Smart subsidies, tax breaks, or low-interest loans can be provided to aid their transition into E2W-related sectors. Likewise, increased investment in building and maintaining charging infrastructure for E2Ws can spur employment opportunities, particularly in areas heavily reliant on fossil fuel-based jobs. Promoting local content in the E2W value chain will also encourage the growth of local E2W manufacturing and the entire value chain by incentivising businesses. This strategy can serve dual purposes – ensuring energy security and creating jobs.

One of the paper's main contributions is the MatCOR framework and model itself. To expand its use and usefulness in the context of transport electrification in SSA, we advise the following to be undertaken as further work:

1. Expansion of the framework and tool to cover a wider set of macroeconomic impacts from E2W transitions, including the impact on labour, supply chains, and the cost of fuel imports. The latter is particularly important in the Kenyan context, for whom liquid fuels made up a quarter of the country's import bill in 2022 (KNBS, 2023) and is the single largest demand on foreign exchange.
2. Use of the framework and tool in other SSA economies, with particular attention paid to the diversity of SSA nations including energy reserves, vehicle stocks and existing infrastructures. In particular, we recommend the analysis of a case with high fossil fuel

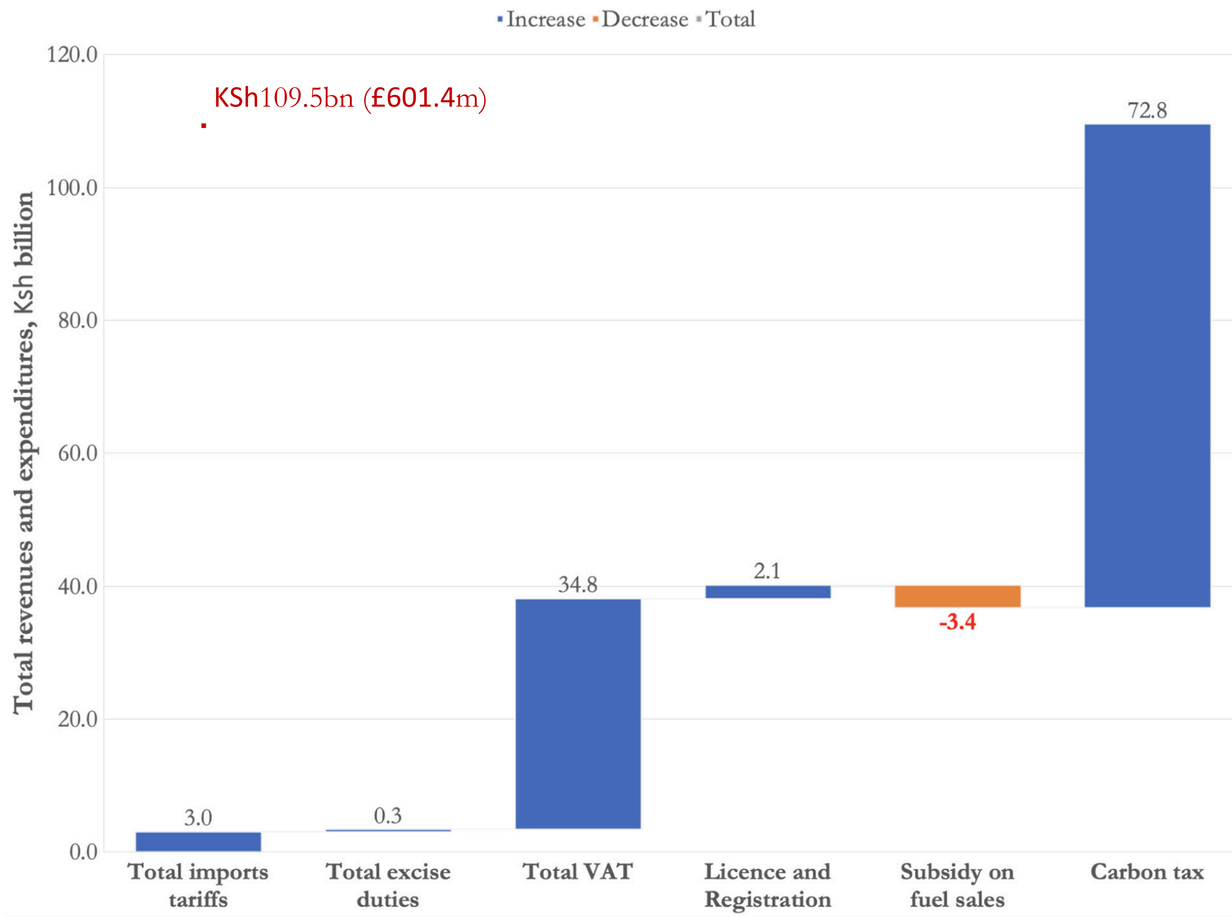

Fig. 8. Forecasted fiscal position for Kenya's Green Growth scenario 2040. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

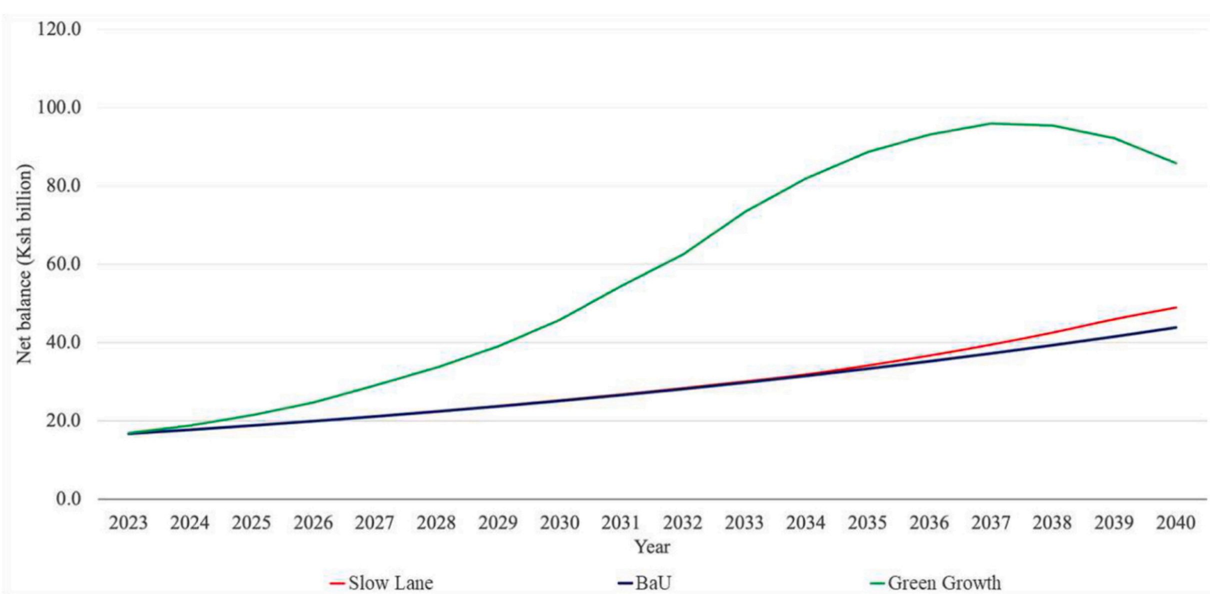

Fig. 9. Compared prediction trends on government net balance for ICE-2 W Base, BAU, and Green Growth scenarios in Kenya (2023–2040). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

reserves (e.g. Nigeria), which we expect to be quite separate from the current case of Kenya (which as discussed at several points has minimal fossil fuel reserves). By conducting this analysis, we expect that a set of policy recommendations for electrification transitions in such states can be developed.

Table 7
Incomes and expenditures for key intervals for BaU scenario broken down into category, 2023–2040.

Fiscal variable	Macroeconomic impact (KSh bn)				
Import tariffs	**2023**	**2025**	**2030**	**2035**	**2040**
Import tariff – ICE-2Ws	1.1	1.3	1.8	2.8	4.5
Import tariff – Spare parts	0.1	0.1	0.1	0.2	0.3
Import tariff - Battery	0.0	0.0	0.1	0.3	0.5
Import tariff - Battery charger	0.0	0.0	0.0	0.1	0.3
Total (imports revenue)	1.2	1.4	2.1	3.4	5.6
Excise duties					
Excise duty - Vehicles	0.4	0.5	0.9	2.2	4.8
Excise duty - Spare parts	0.0	0.0	0.0	0.1	0.1
Excise duty - Battery	0.0	0.0	0.0	0.0	0.0
Excise duty - Battery charger	0.0	0.0	0.0	0.1	0.3
Total (excise duties)	0.4	0.5	1.0	2.3	5.2
Taxes					
Tax – VAT ICE-2W Sales	5.2	5.8	8.0	11.4	16.6
Tax – VAT Fuel Sales	10.2	11.4	14.2	15.9	14.9
Tax – VAT Maintenance	1.6	1.8	2.3	2.6	2.4
Tax – VAT Spare part sales	1.1	1.2	1.5	1.8	1.8
Tax - Insurance Cover	0.2	0.3	0.4	0.5	0.6
Tax - Battery charger sales	0.0	0.0	0.0	0.1	0.1
Tax - Charger installation	0.0	0.0	0.0	0.0	0.0
Tax - Charging station rent	0.0	0.0	0.0	0.0	0.1
Total (tax)	18.4	20.6	26.4	32.2	36.6
Other variables					
Licence and Registration	0.6	0.7	0.9	1.2	1.6
Subsidy on fuel sales	−3.9	−4.4	−5.4	−5.9	−5.2
Total revenue	20.6	23.1	30.4	39.1	49.0
Total expenditure	−3.9	−4.4	−5.4	−5.9	−5.2
Net Balance	**16.7**	**18.8**	**25.0**	**33.2**	**43.6**

3. Production of policy-relevant briefings for SSA governments, to build the evidence base surrounding macroeconomic impacts of electrification transitions and promote coordination of government departments (namely transport, energy and finance) to develop integrated pathways to low-carbon economic growth.

CRediT authorship contribution statement

Emmanuel Uzim: Writing – original draft, Formal analysis, Data curation, Conceptualization. **James Dixon:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data is available in the published open-access tool that accompanies the paper. It is clearly referenced in the paper.

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