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Policy options to mitigate the fiscal impact of road transport decarbonization: the case of Costa Rica

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Abstract

Decarbonizing road transport – through electrification, public transport, and walking and biking – can increase productivity and reduce expenses thanks to reduced traffic and energy efficiency gains. However, governments face losing fuel and vehicle tax revenue. We develop a method to assess options to maintain fiscal revenues without hampering decarbonization benefits. We estimate the financial impact of the transition on the government, firms (buses, taxis, freight, and other private uses), and households grouped by income level and region of residence. Then, we evaluate the impact of energy, property, import, and distance-based tax adjustments on these actors. We apply the method to Costa Rica, a country committed to reaching net-zero emissions by 2050 and where 20% of government revenue comes from transport taxes. Decarbonizing transport would cause a fiscal impact of -0.41% of GDP on average between 2023-50, which is lower than the financial benefits on households and firms: +1.49% of GDP. We show that a combination of tax adjustments would eliminate the fiscal impact while maintaining net benefits for all firms and households of all income levels and regions of residence.

Keywords: Decarbonization; Fiscal Policy; Road Transport; Economic Impacts; Energy Modeling

JEL codes: Q54

1 Introduction

Road transport decarbonization -through electrification, public transport, and walking and biking- will bring socio-economic benefits linked to health and productivity improvements and accident reduction (Bataille et al., 2020; Benavides et al., 2021; Groves et al., 2020; IDB & DDPLAC, 2019; Quirós-Tortós et al., 2021). However, this transformation will reduce fuel sales because of fleet electrification and lower private vehicle ownership and use, thus impacting tax revenue. For instance, in Latin America and the Caribbean, tax revenue from fossil fuels, motor vehicles, and transportation services was 1.1% of the region's Gross Domestic Product (GDP) in 2019 (OECD, 2021). As the transformation unfolds, governments will need fiscal adjustments to compensate for the lower tax revenue (Fullarton, 2018; IEA, 2019).

Few studies have quantified the long-term impact on government revenue from transport decarbonization. The case of Slovenia stands out, where 14.6% of central government revenues in 2016 depended on transport fossil fuel consumption (Elgouacem et al., 2019; OECD, 2019). Decarbonization will also affect their revenue from transport-related technologies. Under a 2°C scenario (i.e., limiting the average global temperature increase to 2℃ by 2100), the Slovenian tax collection on passenger and cargo vehicles (fuel, vehicle registration, and property) would be 13% lower in 2050 than in 2017 (Elgouacem et al., 2019; OECD, 2019). Decarbonization will also impact countries that rely on oil exports for fiscal revenue (Solano-Rodríguez et al., 2021).

Other studies have focused on how fiscal policy can advance decarbonization, e.g., disincentivizing fuel consumption through carbon (Calderón et al., 2014; Carbon Pricing Leadership Coalition, 2019; Chan, 2020; Franks et al., 2018) or road pricing (Axsen & Wolinetz, 2021). The majority of works study how tax incentives can stimulate the adoption of zero-emission vehicles (ZEV). For instance, in the United States (DeShazo, 2016), China (Liu et al., 2021), Europe (Cansino et al., 2018; Lévay et al., 2017; Shafiei et al., 2018), and Latin America (Quiros-Tortos et al., 2019; Urrutia-Mosquera & Fábrega, 2021). However, maintaining them over the long term would exacerbate the future erosion of tax revenues (IEA, 2019).

Once transport decarbonizes, governments will need to find alternative revenue sources to compensate for revenue loss. In this process, they must weigh the different characteristics and effects of tax options. For example, California's Government (United States) introduced a registration fee on electric vehicles (EVs) in 2018 to compensate for the fall in gasoline consumption income. However, its implementation could reduce EV sales by 10-20% (Jenn, 2018). Distance-based taxes are options that manage the externalities of driving (e.g., traffic congestion), stabilizing transportation revenues if governments overcome their implementation challenges [i.e., electronic tolls (van Dender, 2019)]. Carbon taxes can simultaneously advance decarbonization and generate more revenue by pricing carbon but may affect the poorest households (Coady et al., 2019). Governments then need to devise redistribution mechanisms (Steenkamp, 2021) to diminish the impact on vulnerable populations (Vogt-Schilb et al., 2019).

In sum, the existing works focus on using fiscal policy to increase electromobility but seldom address the possible long-term tax revenue shortfall due to lower fuel consumption. Besides, revenue from taxes on vehicles can drop due to fiscal incentives and higher public transport. While tax options exist to increase revenue in the long term, their implementation would cause fiscal costs to firms and households. None of the previous works evaluate the long-term tax revenue effects of transport decarbonization and, simultaneously, assess tax options to compensate for a revenue shortfall considering distributive impacts, i.e., whether the taxes affect low-income or high-income earners –regressive or progressive effects (Horton, 2021)-. Moreover, the lost revenue and necessary adjustments should be dimensioned on par with the benefits of decarbonizing, but such examples are not present in the literature.

This paper presents a two-part method to quantify the fiscal trade-offs of road transport decarbonization, closing the literature gap. First, we use a long-term energy system model to quantify the tax expenses and financial impacts of road transport actors and the government. For firms and households, financial impacts are the additional or reduced expenses attained from decarbonizing relative to a Business as Usual (BAU) scenario where fossil fuels and private vehicle use remain prevalent. For the government, the financial impact (or fiscal impact) is the tax revenue change relative to the BAU.

National financial impacts are the sum of impacts for firms, households, and the government. Positive financial impacts for firms and households are benefits: they spend less with decarbonization than without it. The opposite implies net costs: actors are worse off with decarbonization. Negative fiscal impacts are revenues the government resigns to if it encourages road transport decarbonization without adjusting its fiscal strategy accordingly. Conversely, positive fiscal impacts mean the government earns more by decarbonizing than not. We disaggregate firms into private owners of light-duty vehicles and minibusses, bus operators, taxi operators, and light and heavy freight (i.e., logistics firms). Additionally, we combine household survey data to estimate household impacts by income level and subnational region.

The second part of the method evaluates tax options to eliminate the fiscal impact while accounting for distributional impacts on firms and households. We measure the effect of changing tax rates of property and import taxes on vehicles, fuel taxes -on gasoline, diesel, and liquified petroleum gas (LPG), as well as possible new taxes on electromobility, hydrogen, and vehicle-kilometers-traveled (VKT). The changes eliminate the fiscal impact, i.e., the revenue under decarbonization equals revenue under BAU. The evaluation calculates the fiscal costs for every actor after eliminating the fiscal impact, i.e., raising their transport costs. We carry out two evaluations. One analyzes the individual effect of each option on firms and households, and the other assesses a combination of taxes simultaneously as a mix of options that is more likely to be adopted by governments.

We apply this method to the road transport decarbonization pathway laid out in Costa Rica's National Decarbonization Plan [NDP, (Government of Costa Rica, 2019)], one of the most comprehensive net-zero strategies in the world (Climate Action Tracker, 2021). This Central American country of 5 million and over 12 thousand dollars in GDP per capita (World Bank, 2020) pledges to reach net-zero emissions by mid-century, leveraging its almost 100% renewable electricity system. However, its transport sector causes about 52% of net greenhouse gas emissions (MINAE, 2021) and relies on oil imports of about 2% of GDP (RECOPE, n.d.). Crucially, Costa Rica's transport-related fiscal revenue is 20% of the total (Ministerio de Hacienda de Costa Rica, 2020). Hence, the country stands out for its concurrent high climate ambition and fossil fuel reliance. We build on a national energy model (Godínez-Zamora et al., 2020) produced in partnership with stakeholders during the NDP development and Ministry of Finance databases to model Costa Rica's road transport tax structure. This case study can be helpful to other states, countries, and regions aiming to decarbonize transport with fiscal sustainability.

We find that under base assumptions, the NDP would have a national financial cost of 0.21% of GDP in the mid term (2023-30), which results from adding a negative financial impact of 0.28% of GDP for households and firms, and a positive fiscal impact of 0.07% of GDP. In the long term (2031-50), we estimate an annual national financial benefit of 1.60% of GDP (period average): 2.2% of GDP for households and firms and a negative fiscal impact of 0.60% of GDP. We estimate the annual financial impact in 2023-50 at +1.08% of GDP: a fiscal impact of -0.41% of GDP, but a benefit of +1.49% of GDP for households and firms. We then show that each tax option would have a different distributional impact on firms and households. Increasing the property or vehicle import tax affects households with a higher income who purchase higher value vehicles. Thus, vehicle-based taxes make a promising alternative for a progressive fiscal adjustment. The opposite occurs with vehicle-kilometer-traveled and energy taxes.

Moreover, we show that a combination of tax options can mitigate the fiscal impact with better distributional impacts on firms and households.

The paper is structured as follows. Section 2 describes the method steps described above in more detail, showcasing mathematical relations and simulation assumptions. Section 3 presents the results. Finally, Section 4 discusses conclusions and policy implications.

2 Methodology

2.1 General approach

This subsection presents the general approach that links a long-term energy model with the assessment of financial impacts and the mitigation of fiscal impacts. The following subsections detail some steps of the two-part method depicted in Figure 1. The first part consists of estimating the financial impacts for every actor in the system -fiscal impact for the government. The second part involves studying new tax structures that eliminate a negative fiscal impact while capturing distributive impacts on actors.

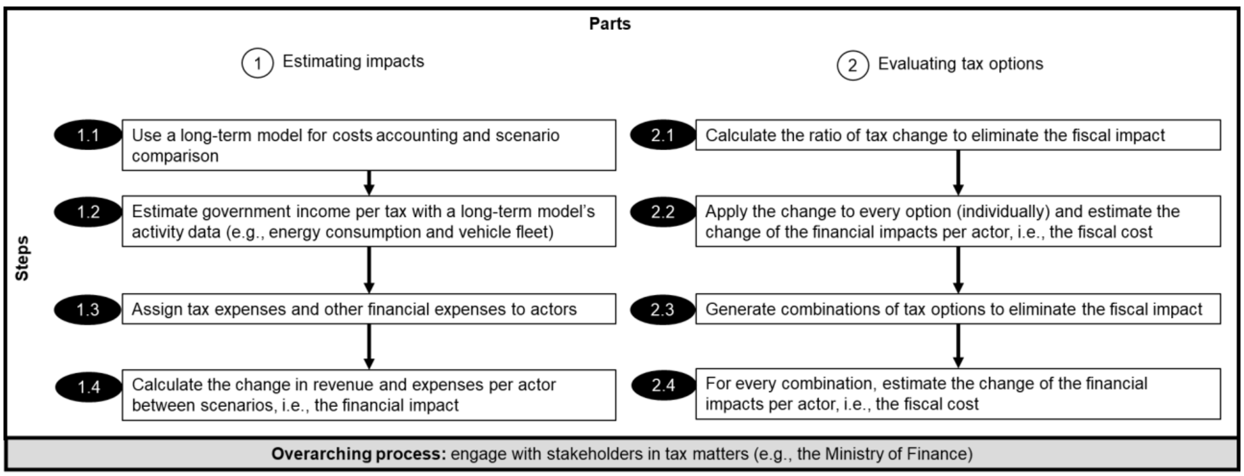


Figure 1. Breakdown of the two-part method.

The first part of the method estimates financial impacts. It uses a long-term energy and transport model for technology cost accounting and scenario comparison (first step). We use OSeMOSYS-CR (Godínez-Zamora et al., 2020) –an implementation for Costa Rica *of the Open-Source Modeling System* OSeMOSYS[1] (Howells et al., 2011). Then, we estimate the tax revenue from every technology in the model (second step). The model provides two inputs: the activity data (e.g., energy consumption, vehicle imports and fleet, and kilometers traveled) and vehicle unit costs. The unit costs are used to estimate the revenue from ad-valorem taxes, i.e., taxes based on the value of an item (Kagan, 2022); the corresponding tax rates are exogenous inputs from the country's regulations. Next, we match technologies to actors and assign

[1] OSEMOSYS is a long-term energy system model framework that coherently accounts for physical variables in the energy system and quantifies the necessary costs to supply sectoral demands (i.e., residential, industrial, transport, and others). In the case of OSeMOSYS-CR, the variables are available yearly for the 2018-2050 period.

tax, capital, and maintenance expenses (third step). Finally, we calculate the difference in revenue and expenses between the decarbonization and BAU scenarios, i.e., the financial impacts (fourth step).

The second part of the method evaluates tax options. The magnitude of the fiscal impact indicates an adjustment ratio (first step) for all taxes, such that the tax revenues of decarbonization and BAU scenarios are the same. We apply the adjustment to every tax option and then estimate the change in the financial impacts for every actor, i.e., the fiscal cost of every tax option (second step). Then, we create random combinations of tax options to eliminate the fiscal impact (third step). Finally, we recalculate all expenses and obtain the fiscal costs per actor and combination (fourth step).

Figure 1 also shows an overarching process: engaging with local experts in tax matters, e.g., the Ministry of Finance in Costa Rica. This engagement process is vital to acquiring data and understanding tax rules; tax authorities will have data and instructions for better modeling. Experts from entities like the Ministry of Finance also understand what other studies and experts visualize for adjustment options and their implications. This element aligns with the robust decision-making (RDM) approach to inform decisions from a long-term future perspective (Lempert et al., 2003).

2.2 Road transport tax structure

The road transport technologies in OSeMOSYS-CR are vehicles brought to the country through international shipping -the country does not have vehicle manufacturing. Importers buy goods from international sellers through a cost, insurance, and freight (CIF) agreement, i.e., the seller covers the costs, insurance, and freight of a buyer's order while in transit via a waterway (Twin, 2021). The vehicle arrives with a CIF value in customs, i.e., what the importer paid the international seller. The importer will then have to pay import taxes to be able to sell the car in the local market.

OSeMOSYS-CR's vehicle capital costs are CIF values per vehicle type, which are then used to calculate the revenue from ad-valorem taxes, e.g., import duties at the customs stage. Countries that manufacture vehicles can alternatively consider invoice prices (i.e., what retailers pay manufacturers) as pre-tax values. The vehicle's market price -paid by the end customers- may include taxes and sales premiums (e.g., for importers and retailers). In Costa Rica, the Ministry of Finance monitors the market prices to define the vehicles' fiscal values, considering their depreciation over time. A vehicle's fiscal value is a proxy of its market price in the local market and is the base to calculate the ad-valorem property tax revenue.

Based on the Costa Rican tax rules, we consider eight specific types of taxes on vehicle owners. Equations 1 to 4 show the tax revenue (TR) -in a year (y)- from the customs duty (CD), the customs value tax (CVT), the motor vehicle excise tax (MVET), and the value-added tax (VAT). These taxes (types one to four) depend on the CIF values of each *k-th* vehicle type, and the corresponding revenue depends on vehicle demand. The government enacts laws and decrees that set each rate in Equations 1 to 4. These equations also depend on the imported fleet size Q^{imp} by vehicle type, and in the case of the VAT, it depends on the estimated profit of retailers (PR).

$$TR_{CD,y} = \sum_{k=1}^{K} \mathrm{CD}_{k,y} \text{ x } \mathrm{CIF}_{k,y} \text{ x } \mathrm{Q}_{k,y}{}^{imp} \quad (1)$$

$$TR_{CVT,y} = \sum_{k=1}^{K} \mathrm{CVT}_{k,y} \text{ x } \mathrm{CIF}_{k,y} \text{ x } \mathrm{Q}_{k,y}{}^{imp}$$	2
$$TR_{MVET,y} = \sum_{k=1}^{K} \mathrm{MVET}_{k,y} \text{ x } \mathrm{CIF}_{k,y} \text{ x } \mathrm{Q}_{k,y}{}^{imp}$$	3
$$TR_{VAT,y} = \sum_{k=1}^{K} \mathrm{VAT}_{k,y} \text{ x } \left(\mathrm{CIF}_{k,y} \text{ x } (1 + \mathrm{CD}_{k,y} + \mathrm{CVT}_{k,y} + \mathrm{MVET}_{k,y} + \mathrm{PR}_{k,y}) \right) \text{ x } \mathrm{Q}_{k,y}{}^{imp}$$	4

Equation 5 computes the tax revenue for property taxes (fifth tax type) and depends on property tax rate tiers. The property tax rate (PT_k) of a vehicle type *k* depends on its fiscal values $\left(FV_{k,\ age}\right)$. A recently imported vehicle's fiscal value equals its market price, and as it ages, it depreciates. We use a representative vehicle for every type, but in practice, other characteristics make a vehicle deviate from the representative cost (e.g., brand or size). Since not all imported vehicles are brand new, CIF values per age are used to estimate fiscal values.

$$TR_{\mathrm{PT},\mathrm{y}} = \sum_{k=1}^{K} \sum_{age=0}^{age_{max}} PT_{k,y}(FV_{k,age,y}) \text{ x } FV_{k,age,y} \text{ x } \mathrm{Q}_{k,age,y}$$	5

Existing vehicle-use taxes apply to fuel and electricity consumption. Eventually, taxes on hydrogen and vehicle-kilometer-traveled (VKT) can be additional options. Equation 6 shows the tax revenue from gasoline (sixth tax type), dependent on the fuel tax rates (FT) and consumption quantities (C). This tax also applies to diesel and LPG. We extract the consumption quantities from OSeMOSYS-CR scenarios in petajoules and convert them to per volume units to compute the corresponding tax revenue.

$$TR_{Gasoline\ ,y} = FT_{Gasoline\ ,y} \text{ x} \sum_{k=1}^{K} C_{k,Gasoline\ ,y}$$	6

Equation 7 shows the electromobility tax (ET) revenue (seventh tax type), which is ad-valorem to electricity or hydrogen prices and relies on the consumption extracted from OSeMOSYS-CR scenarios. We use OSeMOSYS-CR results to compute the levelized cost of electricity and hydrogen, which approximate the end-user prices (P) in Costa Rica (Groves et al., 2020).

$$TR_{Electricity\ ,\mathrm{y}} = ET_{Electricity\ ,y} \text{ x } P_{Electricity\ ,y} \text{ x} \sum_{k=1}^{K} C_{k,Electricity\ ,y}$$	7

Finally, Equation 8 shows tax revenue from vehicle-kilometer-traveled (VKT) taxes (eight tax type), which will depend on the distance traveled (D) per vehicle type. Although inexistent today, taxes on hydrogen and VKT can be additional options in the future.

$$TR_{VKT,\ y} = \sum_{k=1}^{K} VKT_{k,y} \text{ x } D_{k,y} \quad (8)$$

2.3 Road transport financial impacts

Each vehicle type *k* can be assigned to an actor *a*. For every actor, we compute the total expenses (TE) using Equation 9, with K_a being the number of vehicle types belonging to an actor *k(a)*. It sums vehicle purchases (VP, see Equation 10 for estimation), maintenance costs (MC, direct OSeMOSYS estimation), and variable costs (VC) being dependent on fuel, electricity, or hydrogen prices (see Equation 11 for estimation)**.** Equation 9 also considers property tax expenses and bus and taxi services purchases (SP).

$$\begin{aligned} TE_{a,y} &= +SP_{bus,a} + SP_{taxi,a} \\ &+ \sum_{k=1}^{K_a} \left(VP_{k(a)} + MC_{k(a)} + VC_{k(a)} + \sum\nolimits_{age=0}^{age_{max}} PT_{k(a),y}(FV_{k(a),age,y}) \text{ x } FV_{k(a),age,y} \text{ x } \mathrm{Q}_{k(a),age,y} \right) \end{aligned} \quad (9)$$

Crucially, Equation 10 is the multiplication of the market price and the vehicle imports. Hence, this expression contains all the factors that affect the fiscal value used in Equation 4.

$$VP_{a,y} = \sum_{k=1}^{K_a} (1 + \mathrm{VAT}_{k(a),y}) \text{ x } \left(\mathrm{CIF}_{k(a),y} \text{ x } (1 + \mathrm{CD}_{k(a),y} + \mathrm{CVT}_{k(a),y} + \mathrm{MVET}_{k(a),y} + \mathrm{PR}_{k(a),y} \right) \text{ x } \mathrm{Q}_{k(a),y}{}^{imp} \quad (10)$$

Equation 11 is generic for the unit tax (UT) and pre-tax price (P) of fuels (gasoline, diesel, and LPG), electricity, or hydrogen.

$$VC_{a,y} = (1 + UT_{fuel,y}) \text{ x } P_{fuel\ ,y} \text{ x} \sum_{k=1}^{K_a} C_{k(a),fuel,y} \quad (11)$$

Furthermore, we compute the revenue (REV) of bus (and taxi) firms using Equation 12, which depends on the demand of the service (D) and the corresponding fare (SF). The latter is a function of the base year fare and the levelized cost of driving new transport technologies computed with OSeMOSYS-CR results.

$$REV_{bus/taxi,y} = \mathrm{D}_{bus/taxi} \text{ x } SF_{bus/taxi} \quad (12)$$

Finally, Equation 13 shows the total government revenue (GR).

$$\begin{aligned} \mathrm{GR}_y = TR_{CD\ ,y} + TR_{CVT,y} + TR_{MVET,y} + TR_{VAT,y} + TR_{PT\ ,y} + TR_{Gasoline\ ,y} + TR_{Diesel\ ,y} \\ + TR_{LPG\ ,y} + TR_{Electricity\ ,y} + TR_{Hydrogen\ ,y} \end{aligned} \quad (13)$$

Equation 14 defines the financial impacts for a policy scenario (ps) as the difference in revenues and expenses relative to a reference scenario (rs). It applies to all actors: the government, households, bus operators, taxi operators, light and heavy freight firms, and other private firms (light-duty vehicles and minibusses). In the case of the government, we consider its revenue $REV_{government}$ is equal to GR. Except for buses and taxis, we do not estimate revenues for the other actors.

$$FI_{a,y} = \left(REV_{ps,a,y} - TE_{ps,a,y}\right) - \left(REV_{rs,a,y} - TE_{rs,a,y}\right) \qquad (14)$$

The expenses are in USD of 2018 and do not consider inflation. We express the financial impacts in three ways: as a proportion of GDP, 2019 total household expenses, or 2019 total transport expenses (for firms).

2.4 Distribution of expenses

We distribute the fleets between firms and households -imported (${Q^{imp}}_k$) and total (Q_k)-. Once we obtain household fleets, we use the fiscal values to sort vehicle types and ages by value in descending order. We then use ENIGH data to establish the share of ${Q^{imp}}_k$ and Q_k that each quintile purchases (in the case of ${Q^{imp}}_k$) and owns (in the case of Q_k). The highest-income quintiles buy and own the most expensive vehicles (the newest). The next quintile by income gets the second most expensive group of vehicles, and so on until all quintiles are assigned a combination of vehicle type and age.

Households have different bus and taxi consumption patterns. Since these services share a common price, the share of expenses equals the share of service consumption per quintile. The assignations distribute every expense in Equation 9 by quintile and region. These distributions can be estimated using national survey data, which describes how households produce income and spend it in different regions.

2.5 Evaluating tax options

In Costa Rica, the government collects revenue from imports, property, and fuel taxes. Also, there is a value-added tax on electricity consumption covering EVs. Additional electromobility taxes (on electricity and hydrogen consumption) and VKT taxes would be new. This section presents the tax adjustment criteria to eliminate the fiscal impact; the criteria apply yearly and per tax *t*.

Equation 15 shows the condition of adjustment weights *w* per tax. For the individual tax evaluations, the options are: i) property taxes on ICEVs (including hybrids), ii) property taxes on ZEVs, iii) VKT, iv) excise tax (one of the import taxes) on internal combustion engine vehicles (ICEVs), v) excise tax on ZEVs, vi) gasoline fuel tax, vii) diesel fuel tax, viii) LPG fuel tax, ix) electromobility tax on electricity, and x) electromobility tax on hydrogen. Hence, there are ten combinations of weights with a *w* equal to one (individual options).

$$\sum_{t,y} w_{t,y} = 1 \text{, where } 0 \leq w_{t,y} \leq 1 \qquad (15)$$

Equation 16 shows the adjusted unit tax (UT'), which depends on the revenue before adjustments (GR, in Equation 13), the fiscal impact (FI_{gov}), and the adjustment weight *w*. It also depends on the total activity data per vehicle type (AD_k): Q^{imp} (imported vehicles) for import taxes, Q (fleet) for property taxes, C (energy consumption) for fuel and electromobility taxes, and D (distance driven) for the VKT taxes. For taxes that do not exist before the adjustment, the activity data is countrywide (AD^c), e.g., total kilometers traveled or electricity consumption for transport. Equations 15 and 16 apply to every combination.

$$UT'_{k,t,y} = \begin{cases} \left(\left(\mathrm{GR}_y + w_{t,y} \text{ x } FI_{gov,y}\right)/\mathrm{GR}_y\right) * \left(\mathrm{TR}_{k,t,y}/AD_{k,t,y}\right), t \text{ exists before adjustment} \\ \left(w_{t,y} \text{ x } FI_{gov,y}\right)/AD^c{}_{t,y}\,, t \text{ does not exist before adjustment} \end{cases} \tag{16}$$

To avoid arbitrary combinations, we apply a sensitivity analysis to the weight *w*. We arbitrarily produce 1,000 combinations of eight taxes: i) gasoline fuel tax, ii) LPG fuel tax, iii) diesel fuel tax, iv) electromobility tax on electricity, v) electromobility tax on hydrogen, vi) excise, vii) VKT, viii) property taxes. The Latin Hypercube Sampling (LHS) employed to generate the combinations ensures that they are representative of the total possible combinations (Groves & Lempert, 2007). Suppose the possible values of *w* were discrete in steps of 10 (i.e., 0, 10, 20, until 100). In that case, each of the eight taxes would have eleven possible values (8 permutations of 11), yielding more than 6.6 million permutations. Each simulation takes one minute to run with our computing power, so simulating all permutations is prohibitive. Therefore, we define 1,000 samples to complete the simulations in under a day.

The simulations must be re-executed to obtain the fiscal costs per actor, i.e., firms and households by income level. To illustrate the effects of combining tax options, we present an *example combination* that produces even fiscal costs for actors and eliminates the existing EV property tax exemptions explained in the next section. The example combination has the following weights to eliminate the fiscal impact after removing exemptions: 25% for energy taxes[2], 25% for imports, 35% for VKT, and 15% for property taxes.

3 Results and Discussion

3.1 *Case study description*

The OSeMOSYS-CR results provide the activity data for two scenarios: the BAU and the NDP. The scenario assumptions are in Table A.1. The National Household Survey (Instituto Nacional de Estadística y Censos, 2019), or ENIGH (from the Spanish, *Encuesta Nacional de Ingresos y Gastos*), provides data to distribute household transport expenses by income level, both nationally and by region. We use the National Transport Survey (MINAE, 2013) to distribute the fleets between firms and households. We derive coefficients from the ENIGH data that distribute every quintile's expense by a specific country region. The input data to parameterize the method with Costa Rica's case is in the Supplementary Material.

The simulations include tax excise and property tax exemptions -introduced by the Electric Vehicle Promotion Law in 2018- for electric vehicles (Procuraduría General de la República, 2018). Other exemptions include vehicle parts, but these are not studied. After 2023, the tax exemptions on excise taxes are removed in the simulations as per the law. The property tax exemptions remain unchanged

[2] In 2023, the energy tax weights are 6% for gasoline, 9% for diesel, 9% for LPG, 0.2% for electricity, and 0.8% for hydrogen. In 2050, the weights are 4% for electricity, 21% for hydrogen, and 0% for fossil fuels. The shares transition with a linear interpolation from 2023 (high fuel consumption volumes) to 2050 (high electricity consumption).

throughout the period. They reduce the rate as a function of the years since the vehicle's nationalization (the moment when imported): 100% in the first year, 80% in the second, 60% in the third, 40% in the fourth, and 20% in the fifth. In the sixth year and onwards, the exemption is removed.

3.2 Financial impacts of road transport decarbonization

This section presents the financial impacts of the NDP's road transport decarbonization without fiscal adjustments, following the base assumptions of Section 3. Figure 2 shows the yearly average financial impacts on households, firms, and the government (the fiscal impact) for six periods: 2023-25, and then five-year periods until 2050. Households and firms would have a negative financial impact in the 2023-50 period, estimated at -0.28% of GDP. In contrast, the fiscal impact would be +0.07% of GDP due to increased electric vehicle (EV) imports. Therefore, the country would face a net cost of -0.21% of GDP.

In the 2031-2050 period, the financial impacts would be positive for households and firms (+2.2% of GDP) and negative for the government (-0.59% of GDP), resulting in a national net benefit of 1.61% of GDP. In 2023-50 (the whole period), the annual financial impact would be 1.08% of GDP (period average): a benefit of 1.49% of GDP for firms and households and a fiscal impact of -0.41% of GDP.

Figure 2 also shows that the highest fiscal impact is caused by the lost revenue from fuel taxes (light orange). In addition, firms (light blue) have net costs in the first periods until the last decade and households (light green) benefit since 2026. These results show three key points: i) the benefits from decarbonization are enough to redistribute them and mitigate tax revenue losses; ii) the positive fiscal impact in the 2023-30 period allows exploring tax exemptions in the near term that facilitate ZEV adoption, particularly for firms; iii) the most significant fiscal impacts are from 2035 onwards, giving the government about a decade to plan for a fiscal reform compatible with decarbonization and fiscal sustainability.

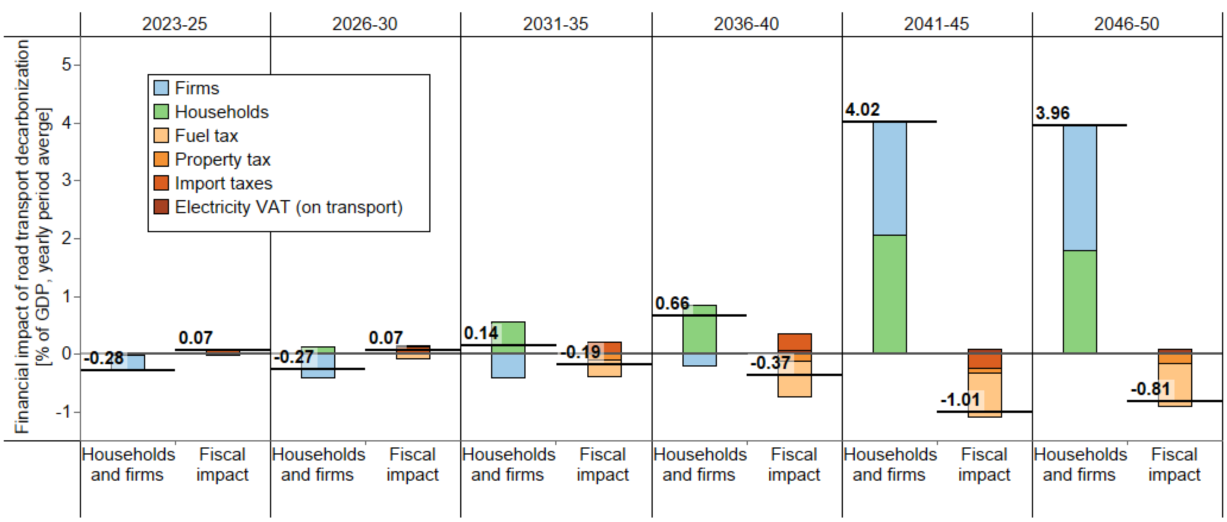


Figure 2. The financial impact of the decarbonization of transport by households, firms, and tax.

The financial impacts exclude economic benefits related to improved air quality or less road congestion; these additional benefits can justify decarbonization despite net financial costs in 2023-30 (the medium term). After 2030, the financial benefits in 2031-50 (the long term) are sufficient to pursue road transport decarbonization. Moreover, the fiscal impact estimates do not account for indirect tax revenues resulting from the financial benefits of decarbonization in households and firms. Businesses and households will use the financial benefits of road transport decarbonization in activities unrelated to transport, which will generate additional revenue for the government. Estimating this indirect collection at 20% of the financial benefit of the actors, based on the average collection in Costa Rica (Ministerio de Hacienda de Costa Rica, 2020), the average annual fiscal in 2023-50 would be only -0.11 of GDP.

The desirable economic results of road transport decarbonization presented above are sensitive to the assumptions, which are inherently uncertain and explored in previous works (Groves et al., 2020). Expensive zero-emission vehicles (ZEVs), high freight transport demands, and low public transport adoption can cause low decarbonization benefits for the NDP (Groves et al., 2020). These risks can increase the government's revenue and reduce the fiscal impact (i.e., making it more positive): e.g., through higher ad-valorem tax revenue from more expensive vehicles and smaller fuel consumption reductions from a large vehicle fleet. Hence, the results presented in this paper are for an economically positive decarbonization pathway to quantify its fiscal and distributive implications.

Figure 3 details the causes of the fiscal impact –values are relative to the BAU. Reduced fuel sales cause the largest fiscal impact due to lower fuel tax revenue: -0.04% of GDP in the medium term and -0.61% of GDP in the long term (yearly period averages). Greater public transport use would reduce the need to own private vehicles (relative to BAU); thus, property taxes. It fiscal impact would be null in the medium term; in the long term, it would be -0.11% of GDP, partly caused by the property tax exemptions.

The electrification of transport would increase the revenue from import taxes in both periods: in the medium term, the higher-income households would buy imported EVs with a lower total cost of ownership (TCO) than internal combustion engine vehicles (ICEVs), despite higher capital costs. This fleet replacement would cause a fiscal impact of +0.11% of GDP. In the long term, with cheap EVs and fewer private vehicles (relative to the BAU), the fiscal impact would be +0.05% of GDP. More EVs in circulation would increase electricity sales, especially in the long term when electrification is massive. Hence, the 13% value-added tax (VAT) on EV electricity would have a fiscal impact of +0.07% of GDP.

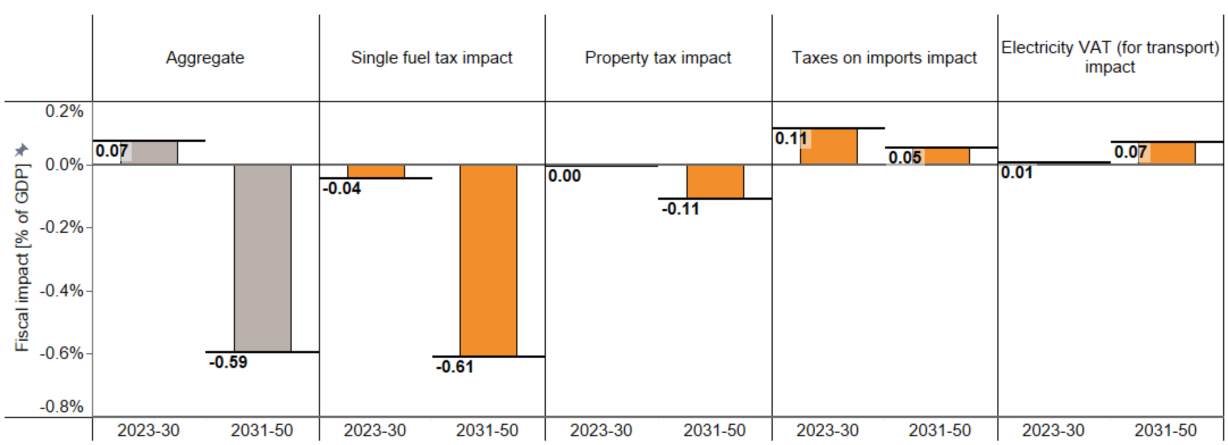
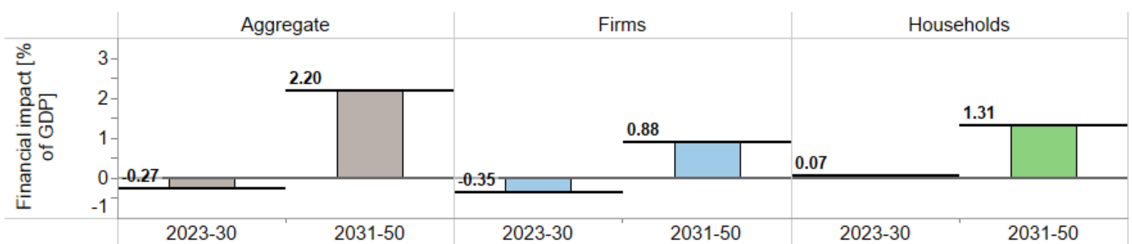


Figure 3. The fiscal impact of transport decarbonization without fiscal adjustments.

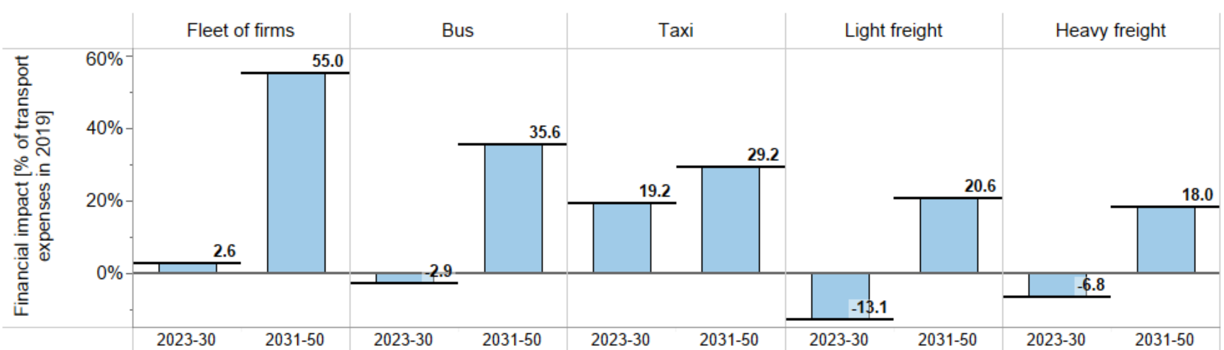
Figure 4a shows the financial impact in the medium and long terms, aggregated and disaggregated for firms and households. Figure 4b, Figure 4c, and Figure 4d show the detailed financial impacts for firms, households by income, and region, respectively. Firms that use light vehicles for their economic activities (fleet of firms) would have the highest financial benefits thanks to the low technological costs of this vehicle type and fuel and maintenance savings. Their financial benefit in the medium term (2.6% of 2019 transport expenses) could increase twenty-one times in the long term (55% of 2019 transport expenses).

Bus firms would have modest financial costs in the medium term (-2.9% of 2019 transport expenses) due to the cost of more buses to meet higher public transport demands. In the long term, the financial impact on bus firms could be about 36% of 2019 transport expenses from reduced unit operational costs. Taxi firms would receive a financial benefit throughout the analysis period. In the medium term, this impact will be around 19% of 2019 transport expenses, and in the long-term, it could increase to 29%.

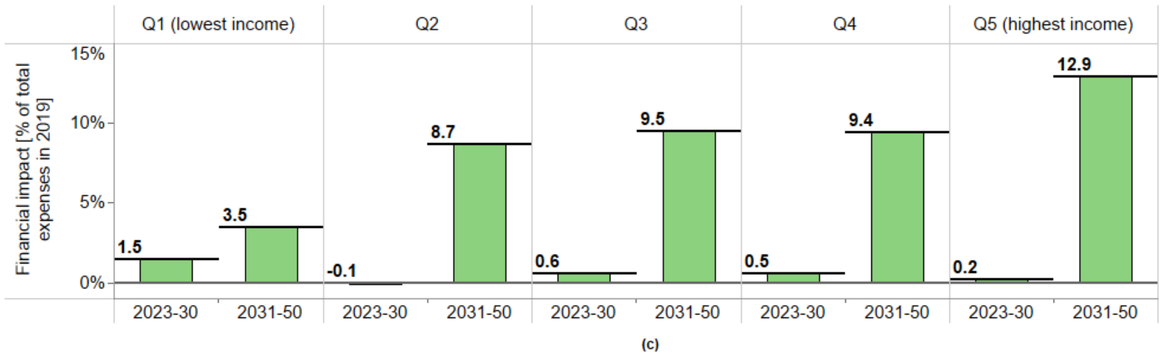
Light and heavy freight firms would adopt EV trucks in the medium term that are relatively more expensive than ICEVs. Hence, light freight firms would have a negative financial impact of 13.1% of 2019 transport expenses in this period, whereas heavy freight firms would be 6.8%. In the long term, when trucks are cheaper, these firms would reach benefits of 21% and 18% of their 2019 transport expenses.



(a)



(b)



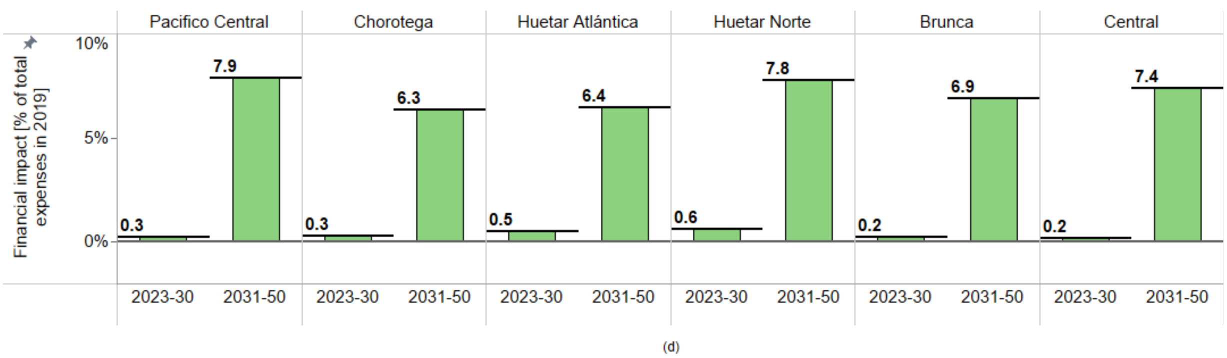


Figure 4. The yearly average financial impact of road transport decarbonization without fiscal adjustments. (a) Aggregate. (b) By company. (c) By income quintile. (d) By region.

Regardless of the income (Figure 4c) or regional location (Figure 4d), households would have an average annual financial benefit that increases significantly in the long term. In the medium term, the financial benefit of households could be below 1.5% of 2019 total expenses. The results of Figure 4c show that, in the medium term, the financial benefits are high for the lowest income quintile, showing how the purchase of expensive EVs falls on wealthier households. Households could attain financial benefits above 3.5% of 2019 total expenses in the long term, mainly for higher-income households that avoid fixed operating costs and vehicle and fuel purchases.

The financial impact of decarbonizing road transport in the medium and long term is homogeneous among households by country region. The regional results are a function of the households-by-income results and the country's existing geographical distribution of wealth. Future work can assess more detailed regional assumptions to explore the financial impacts of road transport decarbonization more in-depth. For example, developing a railway system between two regions can shift their population and composition of transport expenses, thus, affecting the regional impacts.

3.3 *Individual evaluation of tax options to eliminate the fiscal impact*

Here we present the effects on actors of eliminating the fiscal impact with a single tax (see Section 2.5. for the list of individual options). Figure 5 presents the fiscal cost of single-tax impacts (i.e., the change of financial impacts) on firms (5a). Increasing taxes on electromobility, EV imports, kilometers traveled, and EV ownership would entail the highest cost for firms that use light vehicles for their economic activities (fleet of firms). Buses and taxis have little or no impact since they transfer their costs to households through the fare. Raising the tax on LPG, the import of conventional vehicles, gasoline, or the ownership of conventional vehicles would cause the highest cost for light-duty firms. Finally, raising the tax on hydrogen, diesel or LPG would increase the fiscal costs of heavy freight firms, which, in turn, may cause an impact on the cost of goods.

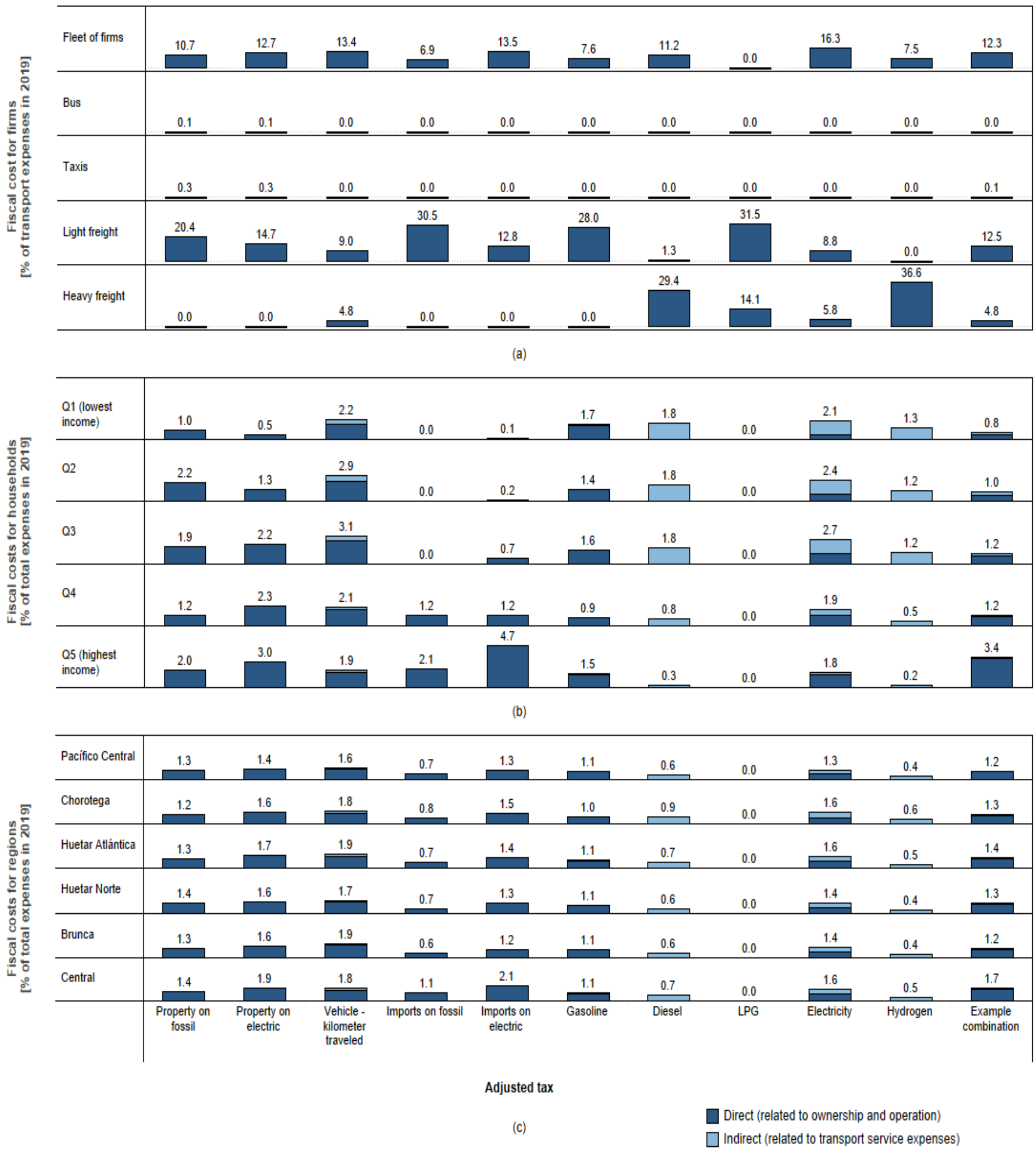


Figure 5. Fiscal cost on firms, households, and regions of transport decarbonization applying one tax option at a time to eliminate the fiscal impact.

Figure 5b shows that increasing the property or import taxes affects households with a higher income since they purchase imported vehicles with a higher market price. This characteristic makes them suitable for a progressive fiscal policy. The opposite occurs with the vehicle-kilometer traveled (VKT) tax, electricity, diesel, and gasoline. While household diesel consumption is minimal, raising the diesel tax would affect public transportation fares, increasing costs for low-income households. Increasing the electricity tax for transportation would affect lower-income households directly (energy for EVs) but would mainly affect them indirectly through the energy consumed by buses and the resulting increased public transportation rates. The effects of the adjustments are homogeneous for regions (Figure 5c). However, changes to the tax on imports and property will bring higher costs for the Central Region, concentrating more on high-income households.

Table 2. The financial impact and tax revenue per tax option in the 2031-50 period for the NDP scenario

	Financial impact				**Tax Revenue**				
Tax option/Metric	**Firms**	**Households**	**Government**	**National**	**Property**	**VKT**	**Import**	**Fuel taxes**	**Electromobility**
Without adjustments	0.88	1.31	-0.59	1.6	1.18	0	1.13	0.27	0.07
Property tax on ICEVs	0.54	1.06	0		1.78				
Property tax on ZEVs	0.61	0.99	0						
VKT	0.61	0.99	0			0.59			
Excise tax on ICEVs	0.47	1.13	0				1.73		
Excise tax on ZEVs	0.62	0.98	0						
Fuel tax on gasoline	0.49	1.11	0					0.86	
Fuel tax on diesel	0.42	1.18	0						
Fuel tax on LPG	0.32	1.31	-0.04					0.83	
Electromobility tax on electricity	0.57	1.03	0						0.67
Electromobility tax on hydrogen	0.38	1.22	0						
Eliminate property tax exemption	0.74	1.16	-0.29		1.47				
Example combination	0.575	1.025	0		1.52	0.11	1.21	0.28	0.12

Note: The blanks mean the rates are unchanged relative to the "Without adjustments" row.

Table 2 shows the long-term financial impacts and tax revenue per tax option -when there is considerable fiscal impact-. Each option affects businesses and households differently. Firms seen as a homogeneous group have higher financial impacts (above 0.6% of GDP) with property and import taxes on EVs (third and sixth row) and with VKT taxes (fourth row); these taxes affect households the most. Changes in taxes on LPG, hydrogen, diesel, and the imports of fossil vehicles have a lower impact on households (without distinguishing income quintiles). LPG taxes do not eliminate the fiscal impact because that fuel is not consumed in the last years of the NDP scenario. The LPG tax exemplifies how taxing fuels may not be compatible with fiscal sustainability in the long term if decarbonization is economically desirable.

Table 2 shows the relative importance of property and import taxes before adjustments (71% of the NDP's tax revenue) and how a revenue source can increase -as much as the fiscal impact- depending on the tax option. While the results look forward to 2050, more analyses and reforms would be necessary afterward if deep uncertainties arise, e.g., local vehicle manufacturing (eliminating imports) propelled by 3D printing. Figure 5 and Table 2 include the *example combination* defined in section 2.5.; it is explored next.

3.4 Combining tax options to eliminate the fiscal impact

Using a single policy option to eliminate fiscal impact would disproportionately affect some actors; for example, increasing the LPG tax would mainly affect freight firms (see Figure 5). Combining tax options better distributes the fiscal costs across actors. The financial impacts under the example combination (see section 2.5. for its details) are in Figure 6 (red points) compared to individual tax options (light blue points): the example combination does not cause the minimum or maximum financial impact for any actor.

The example combination eliminates the property tax exemptions in the long term. Table 2 showed that by only eliminating those exemptions, the long-term fiscal impact would drop by half, to just -0.29% of GDP in 2031-50 (Table 2, second last row, third column). The elimination of the exemptions in the long term keeps positive benefits for firms and households and impacts the wealthiest households the most (Figure 5b, last column). The combination also diversifies the sources of tax revenue (Table 2, last row), which would be convenient depending on the administrative cost of each option, unexplored in this work.

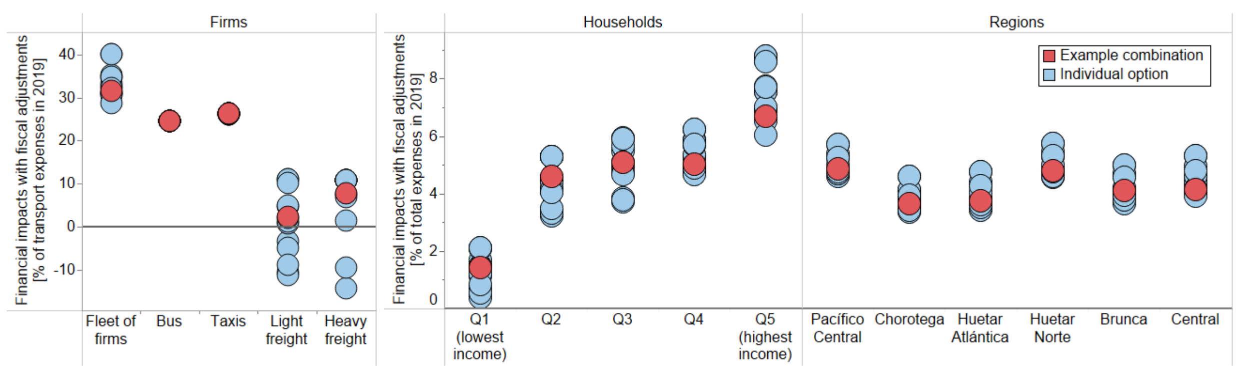


Figure 6. The financial impact of a combination of options and contrast with individual options. The values show the annual average for the period 2023-50.

Table 3. Average tax rates per option in the 2046-50 period for the NDP scenario

Tax Option/Tax	**Property tax* [% of fiscal value]**		**Vehicle-kilometer traveled tax [USD/thousand kilometers]**	**Excise tax* [% of CIF value]**		**Fuel tax [relative to 2019]**			**Electromobility [% of energy price]**	
	ICEVs	**ZEVs**		**ICEVs**	**ZEVs**	**Gasoline**	**Diesel**	**LPG**	**Electricity**	**Hydrogen**
Without adjustments	3.2	3.3	0	30	30	1	1	1	13	0

Property tax on ICEVs	20	3.3								
Property tax on ZEVs	3.2	6.1								
VKT			28.5							
Excise tax on ICEVs				216	30					
Excise tax on ZEVs				30	81					
Fuel tax on gasoline						68	1	1		
Fuel tax on diesel						1	48	1		
Fuel tax on LPG						1	1	189		
Electromobility tax on electricity									123	0
Electromobility tax on hydrogen									13	213
Example combination	3.4	3.5	6.8	38	37	1.2	1.4	2.6	16	28

Note: *the rates are for hybrid (ICEV category) and BEV SUVs – there aren't ICEV imports in this period; thus, selecting hybrids is necessary to obtain a rate. Also, the blanks mean the rates are unchanged relative to the "Without adjustments" row.

The combination of options also avoids high tax rates. Table 3 shows the rates (average in the 2045-50 period) obtained for the example combination. The combination would have the following characteristics:

- It would require a low property tax rate due to removing the corresponding tax exemption.
- It would lead to a VKT tax rate four times lower than the necessary one if it were used individually.
- It would lead to an excise tax lower than half the value otherwise needed with only excise taxes.
- It would require fuel tax increases: 1.2 times the 2019 value for gasoline, 1.4 times for diesel, and 2.65 times for LPG. These increases are markedly lower than the values tens of times higher if only one fuel tax option were used.
- It would require an average annual tax on electricity of 16% and 28% for hydrogen. These values are lower than the 123% or 213% required if the government only uses electromobility taxes.

In sum, the combination allows each good or service to be priced moderately (avoids high taxes) and achieves a balanced cost for the actors.

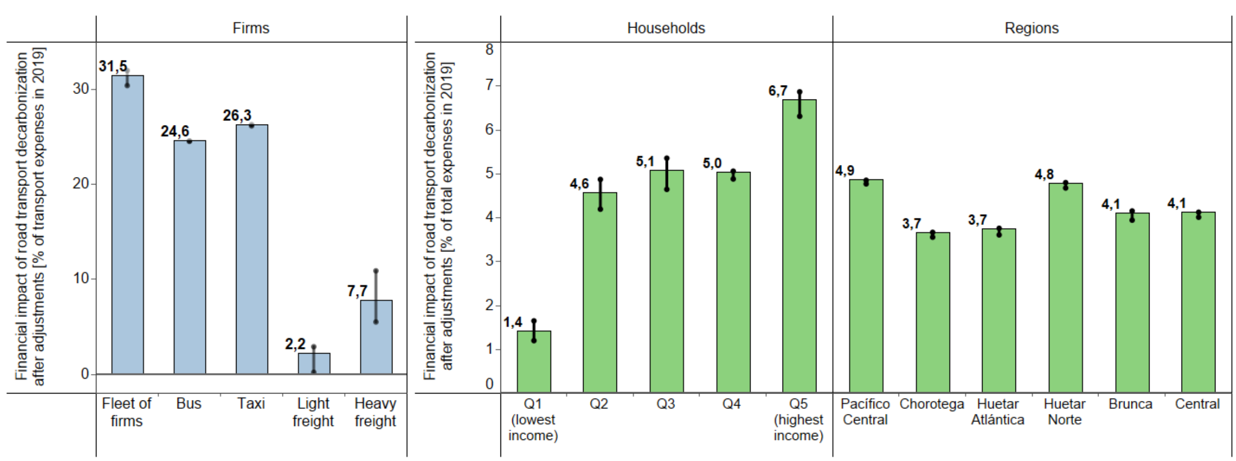


Figure 7. The financial impact on firms, households, and regions of transport decarbonization with fiscal adjustments using tax combinations.

Figure 7 shows the average effect (bars) of the 1,000 combinations (see section 2.5. for details) and the variation range (black vertical lines). Since the variation range is relatively small in Figure 7 for all actors, the combinations maintain positive benefits. Only light freight firms have a range reaching almost zero benefits. Future work should explore the tax combinations on par with an uncertainty assessment of technological costs, performance, and social preferences (e.g., public transport use). These factors would likely produce a wider variation range for the metrics than the tax options alone. The appropriate tax combinations may change depending on the decarbonization pathway and the uncertainties.

4 Conclusions and Policy Implications

With the current tax rules, decarbonizing road transport in Costa Rica, according to its National Decarbonization Plan (NDP), would decrease tax revenue from vehicle imports, vehicle property taxes, and fuel or energy consumption. In the country's current context (COVID-19 recovery, 2019 tax reform, high unemployment, and 20% reliance on transport activity for fiscal revenue), the goal of decarbonizing must align with fiscal sustainability. The good news is that the NDP's financial benefits would outweigh the unrealized tax revenue from not decarbonizing (or a BAU scenario).

The benefits are the avoided fuel and vehicle expenses -relative to the BAU- if the country implements a road transport decarbonization path, such as the NDP. If they are negative, the BAU is more beneficial than the NDP, which is the case for the government. We estimated the annual financial benefit of road transport decarbonization at +1.08% of GDP (yearly 2023-50 average). The benefits would be +1.49% of GDP for households and firms but -0.41% of GDP for the government (i.e., a negative fiscal impact).

The financial benefits understate the full benefit of decarbonizing road transport. Adding other economic benefits, such as the reduction of accidents, improved air quality, and increased productivity by reducing the time lost in road congestion, the decarbonization of transport entails an economic benefit of US $ 20 billion between 2021 and 2050 (Godínez-Zamora et al., 2020; Groves et al., 2020). Therefore, governments like Costa Rica can formulate a tax structure that redistributes benefits -eliminating the negative fiscal impact- while meeting environmental and economic development objectives.

Our work contributes to the literature in multiple ways. It provides a case study similar to Slovenia's (OECD, 2019) -a country in Europe with more than 14% of revenues dependent on fossil fuels- that estimates tax revenue changes from implementing climate policies. However, we also evaluate ten different individual tax options and 1,000 possible tax combinations to ensure that tax revenue is equal with or without decarbonization. In the literature, only one study assessed the introduction of a registration fee to compensate for the fall in gasoline consumption in California (Jenn, 2018); most studies focus on incentivizing electric vehicle (EV) adoption or penalizing fossil fuels.

The first policy implication of our work is the quantification of the magnitude and timing of fiscal impacts. Governments could determine when a tax reform would be needed under their road transport decarbonization plans. While our case study focused on one country and one scenario, the approach can be adjusted for different jurisdictions and more scenarios for other applications. In the particular case of Costa Rica, a country reliant on transport-related tax revenue, our findings suggest that a successful decarbonization process by 2030 requires a tax reform to eliminate the fiscal impacts after that year.

The second policy implication is the contemplation of fiscal costs and tax rates. Different technology use rates lead to different fiscal costs to firms, high-income and low-income households. Our results show that combining different tax options distributes actors' costs and leads to moderate tax rate increases. Citizens could accept a reasonable tax rate increase if their overall transport costs decrease (i.e., they attain benefits). Suppose governments pursue one single option to eliminate the fiscal impact. In that case, high tax rate increases would distort the final price of the transport good or service, making the government not accomplish its fiscal sustainability objectives. Policymakers can also judge tax options by their capacity to generate stable fiscal revenue long-term, whether the options internalize social costs (linked to price efficiency), and by the ease of implementation in their jurisdiction (e.g., countrywide) (van Dender, 2019). Other measures of merit for options are cost-effectiveness, equity impacts, and political acceptability (Axsen & Wolinetz, 2021; Haar, 2020).

The third policy implication is an alert about the fiscal sustainability of currently popular tax options. Carbon taxes are expected to be effective tools to decarbonize (Carattini et al., 2018; Malerba et al., 2021), along with electromobility adoption tax incentives (Cansino et al., 2018). However, there will be necessary tax adjustments after the integrated decarbonization policies (Axsen et al., 2020) start steering the technological composition of the transport sector.

One limitation of this study is that it does not quantify the uncertainty of the decarbonization process. Future work could explore the NDP's financial impact on households, firms, and the government (fiscal impact) under uncertainties like fuel and technology costs and transport demands (Groves et al., 2020). Further, the work could identify the trade-offs governments could face when deciding what taxes to enforce depending on how key uncertainties unfold. The bottom-up technological modeling we achieved in this paper could enable the insights mentioned above.

The second limitation is the analysis of endogenous tax effects. Other quantitative techniques could complement our bottom-up accounting and scenario comparison approach to understand the impact of tax changes on incentives (for example, whether taxing electricity in the short term discourages the purchase of electric vehicles). General Computable Equilibrium Models [GCEM (Lallana et al., 2021; Langarita et al., 2021)] and other dynamic models (Ugarte et al., 2021) could offer such capabilities. Moreover, this work does not study the administrative and political feasibility of the evaluated options (for example, taxing electricity or LPG used for transportation differently). The International Energy Agency (2019) (IEA, 2019) report presents a qualitative overview of these issues.

The work serves as a reference for detailed fiscal quantifications that shed light on the transformative processes similar to the National Decarbonization Plan. Our findings can play an essential role in ensuring a robust plan implementation while contemplating fiscal sustainability. Finally, this study provides a useful example for other countries and development institutions interested in studying the fiscal impact and its relationship to long-term decarbonization strategies.

5 Acknowledgments

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Appendix

Table A.1. Scenario assumptions applied to this study.

Variable	Detail	Scenario	Assumption
Passenger transport (units in passenger kilometers)	Public transport demand in 2018	Both	Under 25% of passenger demand
	Public transport demand in the future	BAU	Unchanged
		NDP	Increases to 32.5% in 2035 and 45% in 2050 of demand
	Rail transport	NDP	In 2050, it mobilizes 1.2 Gpkm (about 15% of the public transport demand in 2018)
	Non-motorized (pedestrian and bicycle) transport and telework		It becomes 4% in 2035 and 10% in 2050 of the NDP's passenger transport demand. These numbers include avoided private transport demand due to telework.
	Private transport demand in the future	NDP	Becomes 45% in 2050
		BAU	Stays at 75% in 2050
Demand projections	GDP growth	Both	GDP growth is 3% yearly from 2023 onwards; the previous years use historical values or forecasts.
	Freight transport demand elasticity to GDP		1.015*
	Passenger transport demand elasticity to GDP		0.916* until 2024; then decreases linearly until 0.75
ZEV penetrations and other measures	Heavy freight (BEVs and FCEVs)	NDP	10% in 2030 and 95% in 2050
	Light freight (BEVs)		30% by 2035 and 85% by 2050
	Buses and minibusses (BEVs)		30% in 2035 and 85% in 2050
	Buses and minibusses (FCEVs)		3% in 2030 and 10% in 2050
	Taxis, sedans, SUVs, and motorcycles (BEVs)		35% in 2035 and 99% in 2050
	LPG in heavy and light freight		20% in 2030, but 0% in 2050
ZEV capital cost reductions relative to 2018	For buses, minibusses, light trucks, and SUVs (for BEVs)	Both	31% by 2030 and 34% by 2050
	For motorcycles (for BEVs)		Unchanged
	For sedans (for BEVs)		33% by 2030 and 37% by 2050
	For heavy trucks (for BEVs)		3% by 2030 and 9% by 2050
	For buses, minibusses, and heavy trucks (for FCEVs)		3% by 2030 and 7% by 2050
Other costs	The costs of ICEVs	Both	Remain constant
	The capital costs of BEVs		Double the ICEV counterparts
	The capital costs of FCEVs		About 3.5 times higher than the ICEV counterparts
	The maintenance costs of BEVs		One-third of the ICEV's values. They remain constant.
	Fossil fuel unit costs (imports)		Increase 1.9% yearly

Note*: the elasticities result from analyzing the Ministry of Finance's historic vehicle databases.