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Assessing the Impacts of Introducing of Carbon Tax and Technologies for Road Transportation in Laos

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This paper applied the AIM/CGE [Laos] model to assess impacts of introduction CO_2 mitigation actions in the transport sector through the comparison for energy consumption, GDP growth and CO_2 emissions in Laos. The introduction of CO_2 mitigation actions/countermeasures (CMs) include carbon tax, electric vehicles (EV), biofuels, and subsidy. The model results of BAU scenario show the total final energy consumption will increase in 2050 by 123 %. By introducing EV and biofuels exogenously with carbon tax and subsidy, it is observed that the final energy consumption will reduce gradually in the long-term. GDP will gradually decrease with a loss of 1.9 % by 2050 in case of the countermeasures scenario comprising EV and biofuels plus carbon tax and subsidy policy. The CO_2 emission in BAU scenario will increase remarkably at a growth rate of 184 %. EV and biofuel plus carbon tax will result in 57 % decline of CO_2 emission in 2050, and the subsidy policy will lead to the greatest fall of CO_2 emission. Introduction of carbon tax alone in transport sector will not have any influence on household behavior for energy consumption in both short-term and long-term, resulting in no impact on CO_2 emission. Nevertheless, applying mitigation actions (EV and biofuel) plus carbon tax, and subsidy countermeasures can be a significant driver for influencing final energy consumption and CO_2 emission reduction. But introducing the mitigation countermeasures, except for carbon tax, will result in a gradual decline of the GDP growth in the long-term.

1. Introduction

In the Vision 2030 document, Laos has a clear pathway for green and sustainable social-economic development, Laos foresees to transition from a least developed country a developing country with upper-middle income and with innovative, green and sustainable economic growth (MPI, 2016). The ten-year National Social-Economic Development Strategy for 2016-2025, in consistent with the Vision 2030, also emphasizes inclusive and sustainable growth as being the way forward (MPI, 2016). Following the long-term vision and plans, The Decree on Climate Change was formulated and adopted in 2019, which defines principles, regulations, and measures on management, monitoring of climate change matters (Lao PDR, 2019).

Based on the direction of long-term policies, Laos has taken ambitious steps towards reducing its emission in its Nationally Determined Contribution (NDC) (Lao PDR, 2015). For example, targets such as increasing the share of small-scale renewable energy to 30 % of total energy consumption by 2030 and promoting bio-energy consumption in 10 % of transport sector by 2030, are introduced (Lao PDR, 2011).

Nowadays, Laos is a country with low greenhouse gas emissions and is also a country with the absorption capacity higher than the emissions and the greenhouse gas emissions in the Lao PDR has slightly decreased from 50,700 Gg $CO_{2\text{-eq}}$ in 2000 to 24,100 Gg $CO_{2\text{-eq}}$ in 2014 (MONRE, 2013, 2021). The estimated GHG emission under baseline scenario, is projected to reach around 82,000 Gg $CO_{2\text{-eq}}$ in 2020 and 125,000 Gg $CO_{2\text{-eq}}$ in 2050, (MONRE, 2020). One of the drivers of this high expansion rate is an increase of vehicles. The main mode of transport in Laos is private vehicles. The number of vehicles is expected to reach around 3.8 M in 2030 and 6.6 M in 2050 (Khamphilavanh and Masui, 2021). Energy-related emission is a significant emission source. In 2014, energy-related emission sources were the second largest, at 3,700 Gg $CO_{2\text{-eq}}$, accounting for 15 % of

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national emission. The emission from fuel combustion in transportation accounted for 62 % of the energy-related emission (MONRE, 2021).

Carbon tax is an effective mitigation tool for curtailment of emission, and several developed and developing countries have applied this mechanism globally. The state of the National Green Growth Strategy (NGGS) of Laos stated that carbon tax could be a significant measure to restrict the import and use of personal vehicles (NGGS secretariat, 2018). This was also consistent with the objective the Environmental Protection Law that aims to ensure balance between social and natural environment (Lao PDR, 2013). But carbon tax has not been considered as a mitigation countermeasure in Laos, so in order to provide a scientific evidence for policy to spur green production and consumption in the country, there is a need to assess the impacts of carbon tax policy. The objectives of this paper are to assess the impacts of introducing CO2 mitigation actions/countermeasures (CMs) such as carbon tax, mitigation technologies (EV and bioenergy) and subsidy through the comparison of energy consumption, annual GDP growth rate and CO_2 emissions in Laos by using national scale computable general equilibrium (CGE) model.

2. Data and Method

2.1 Method

The AIM/CGE [Laos] model which was developed by Asia-Pacific Integrated Model (AIM) team (Masui et al., 2011), (Okagawa et al., 2012), is applied to assess the introducing GHG mitigation actions for private vehicles, namely, electric vehicles and biofuel use, and adopting a carbon tax and subsidy for limiting emission from transport sector in Laos, in this study. The AIM/CGE [Laos] is a national scale computable general equilibrium model with recursive dynamics, and total 42 commodities have been considered, as shown in Table 1. Each sector has nested production function with conventional/advanced technology and new/existing capital as shown in Figure 1. GHG emissions from fuel combustions and activities such as IPPU, waste and agriculture are taken into account in the model.

Table 1: List of 41 commodities in AIM/CGE [Lao]

Commodity	Commodity	Commodity
1. Cropping	18. Electrical and optical equipment	32. Other supporting and auxiliary transport activities; activities of travel agencies
2. Livestock	19. Transport equipment	33. Post and telecommunications
3. Forestry	20. Manufacturing, nec; recycling	34. Financial intermediation
4. Fishing	21. Electricity [Hydropower and Coal thermal power]	35. Real estate activities
5. Mining and quarrying	22. Water	36. Renting of M&Eq and other business activities
6. Food, beverages, and tobacco	23. Construction	37. Public administration and defense; compulsory social security
7. Textiles and textile products	24. Sale, maintenance, and repair of motor vehicles and motorcycles; retail sale of fuel	38. Education
8. Leather, leather products, and footwear	25. Wholesale trade and commission trade, except of motor vehicles and motorcycles	39. Health and social work
9. Wood and products of wood and cork	26. Retail trade, except of motor vehicles and motorcycles; repair of household goods	40. Other community, social, and personal services
10. Pulp, paper, paper products, printing, and publishing	27. Hotels and restaurants	41. Private households with employed persons
11. Coke and nuclear fuel	28. Inland transport	42. Biofuel
12. Refined petroleum	29. Water transport	
13. Chemicals and chemical products	30. Air transport	
14. Rubber and plastics	31. Other supporting and auxiliary transport activities; activities of travel agencies	
15. Other non-metallic minerals		
16. Basic metals and fabricated metal		
17. Machinery, nec		

Hydro electricity and biofuels are treated as clean energy options. The electricity in Laos is produced from two main sources; renewable energy generated by hydro power plants, and electricity generated by coal power plants. The future capacity of each power plant is set as a scenario, but the production of electricity is calculated endogenously. Biofuel is a substitute for fossil fuels in transport sector. The necessary material inputs for producing biofuels are agricultural products such as palm and jatropha fruits. The production process still generates CO_2 emission since fossil fuel is needed for palm mill processing and blending palm oil with fossil fuels.

In transport service, conventional technology comprises vehicle which needs fuels, and currently the share of conventional vehicles in Laos is 100 %. The advanced technology vehicle has multiple advanced options; for examples, vehicle with more efficient energy combustion that less CO_2 emission, when compared to the

conventional vehicle (Shukla and Dolcera, 2009). In this analysis, EV is regarded as advanced vehicle. It needs only electricity and its dissemination will be able to contribute to reduce CO_2 emissions, since it consumes cleaner energy, particularly electricity that is generated from hydropower plants. New 36 hydro power projects are being constructed with capacity to produce energy of 20,890 GWh/y (MEM, 2018). Introduction of EV is regarded as a mitigation option for transportation. Based on government target, the share of biofuel is assumed to increase from 10% in 2025 to 40% in 2050. Figure 2 shows the CGE model structure of energy demand in household sector.

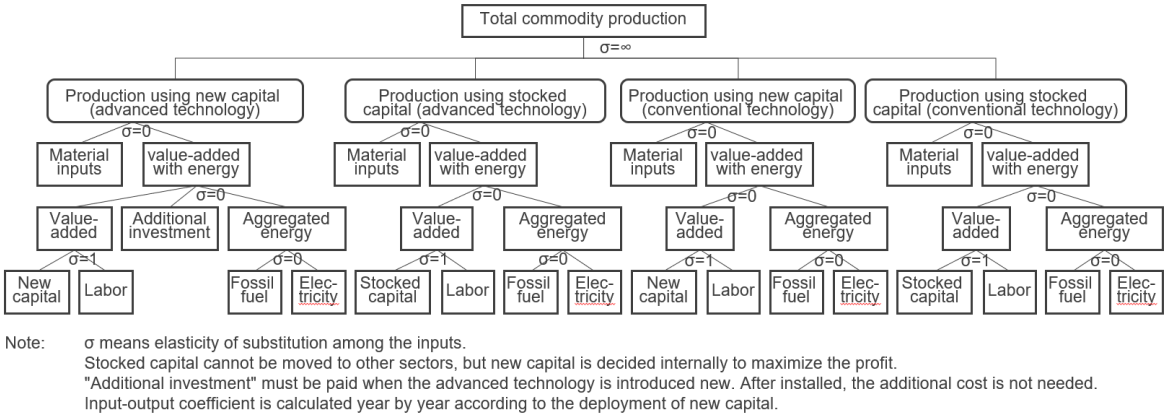

Figure 1: CGE structure for production sector

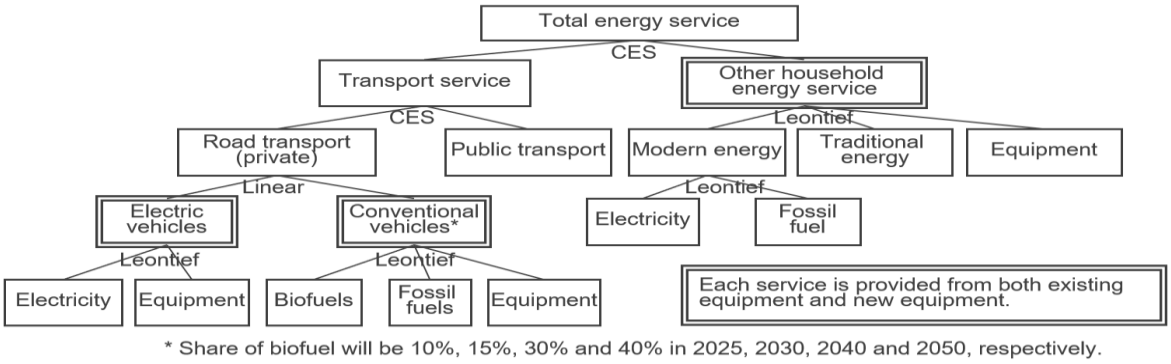

Figure 2: CGE structure of energy consumption in household sector

2.2 Data

The main data to develop the AIM/CGE [Laos] model is based on Laos input-output (IO) table in 2014, which was developed and published by ADB in 2018 (ADB, 2018) with a total of 35 sectors. The decision to choose this dataset as the main data is due to the most recent national GHG inventory availability. In this study, some sectors are disaggregated into more detailed sectors such as hydro power plant and coal thermal power plant based on their energy sources. In addition, biofuel production sector is added. The information related to the bioenergy production is obtained from renewable energy development strategy of Lao government (Lao PDR, 2011). Besides the data mentioned above, other socio-economic data like GDP, trade balance, power generation capacity, and population growth are needed for the simulation.

2.3 Scenario

In this study, Business as Usual (BAU) scenario and countermeasure scenarios are prepared as shown in Table 2. In both scenarios, the annual GDP growth rate from 2020 to 2050 is assumed to be 5.7 %/y. Population growth rate from 2020 to 2050 is assumed to be 1.2 %/y.

BAU scenario is a reference case with no mitigating countermeasures policy. In countermeasure scenarios, the socio-economic assumptions are the same except introduction of mitigating countermeasures, namely, carbon tax (10 USD/t CO_2), mitigation options such as EV technology with certain market penetration levels, biofuel with carbon tax (10 USD/t CO_2), and subsidy for mitigating the cost of EV technology. The EV technology, which

had a 1 % penetration in 2020, is assumed to replace conventional vehicles in households by 14 % in 2025, 30 % in 2030, and 50 % in 2050, in the countermeasure scenario (MEM, 2020). In this analysis, it is assumed that carbon tax will be introduced endogenously as a mitigation measure for supporting biofuel promotion. In the countermeasure scenario, the biofuel production will increase by 5 %/y. The technology plus carbon tax will also exogenously stimulate the increase of biofuel by 5 %/y. In this scenario, the subsidy will endogenously reduce the EV cost (table 2). It is assumed that Lao government will introduce the carbon tax and subsidy for EV technology. In order to introduce the EV, each sector will need to pay more as an "additional cost" in Figure 1. In this analysis, the cost of EV is taken as 50 % more as compared to the conventional vehicle, which is the cost of electric equipment including battery. To diminish the cost, the government should consider subsidy. However, the conventional vehicles user will need to pay for carbon tax. Through the comparison of energy consumption, GDP and CO_2 emissions in these scenarios, the impacts of introducing carbon tax and mitigation technologies for road transportation in Laos is assessed in this analysis.

Table 2: Scenario in this analysis

Scenario	Carbon tax	Subsidy	EV	Biofuel
BAU	-	-	-	-
Tax$10	10 USD/t CO_2	-	endogenous	5 %
Tech+$10	10 USD/t CO_2	-	exogenous	5 %
Subsidy	-	subsidy	endogenous	-

3. Result and Discussion

This section presents the results of the scenario analysis for road transport sector in Laos. The results for BAU and countermeasure scenarios are presented along the lines of energy consumption, CO_2 emissions, and impact on GDP growth.

3.1 Comparison of final energy consumption

Figure 3 presents the total final energy consumption in the BAU and countermeasure scenarios between 2014 and 2050. It can be seen that, in BAU scenario, the final energy consumption will increase from 2,600 ktoe in 2014 to 3,800 ktoe, 4,800 ktoe and 5,900 ktoe, representing total growth rates of 45 % in 2030, 80 % in 2040, and 123 %, in 2050. However, the scenario of introduction of carbon tax countermeasure alone at 10 USD/t CO_2 will have no significant impact on energy consumption. This is because 10 USD/t CO_2 may not be enough to replace the conventional vehicle by EV.
AIM CGE is recursive dynamic model in which energy efficiency improvement and energy switch are derived from the introduction of new equipment. However, the additional cost of EV is very high and therefore it is hard to select EV endogenously. By introducing EV and biofuels exogenously with carbon tax or subsidy, it is observed that, compared with BAU scenario, the final energy consumption will gradually reduce in 2040 and 2050. The total final energy consumption in 2040 will fall from 4,800 ktoe in BAU to 4,600 ktoe in that countermeasure scenario, accounting for 3 % reduction. In 2050, final energy consumption will decrease from 5,900 ktoe in BAU to 5,700 ktoe in the countermeasure scenario, accounting for 4 % reduction.

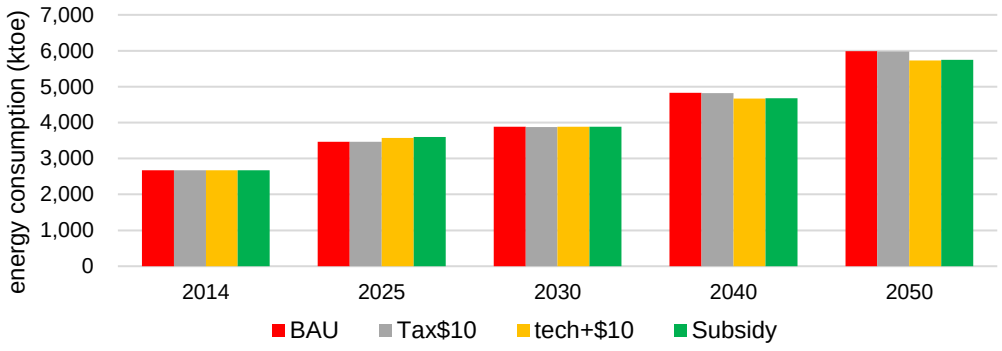

Figure 3: Total final energy consumption in BAU and countermeasures scenario.

3.2 Comparison of annual GDP growth rate

GDP growth in BAU and that in the scenarios with introduction of the EV and biofuel with carbon tax and subsidy are compared. Since the cost of the electric vehicles is higher than the cost of the conventional ones, promoting

EVs may have some negative economic impact. Carbon tax and subsidy policies may also create some impacts on annual GDP growth rate. Figure 4. shows that the carbon tax at 10 USD/t CO_2 scenario will have no negative impact on GDP growth. This carbon pricing will not impact the consumption behavior of households. This might be because the people will have not much options for fuels selection and there will be limited public transport services, and consequently travel by their own private vehicles will still be the most convenient way. But the GDP value will gradually decrease during 2030-2050 in the countermeasure scenario comprising EV and biofuels plus carbon tax. The GPD loss will be about 353 M USD, accounting for 1 %, in 2030; 900 M USD, accounting for 1.6 %, in 2040; and 1,780 M USD, accounting for 1.9 %, in 2050. The GDP loss may be due to the introduction of subsidy policy by the government. Specifically, the government will lose the tax income from mitigating import tax for import of EV technology and will spend more foreign currency for importing EV since the cost of EV is higher than conventional vehicles.
The subsidy scenario will have smaller disadvantage than mitigations plus carbon tax scenario. For examples, the GPD loss will be about 25 M USD, accounting for 0.1 %, in 2030; 249 M USD, accounting for 0.4 %, in 2040; and 750 M USD, accounting for 0.8 %, in 2050.

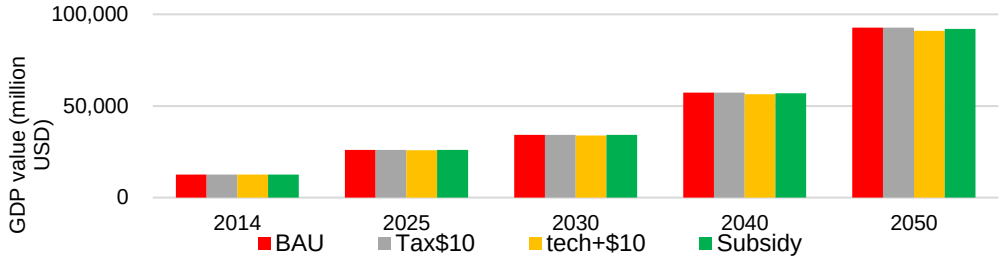

Figure 4: Comparison of GDP value in the BaU and countermeasures scenarios

3.3 Comparison of carbon dioxide emission

Figure 5. displays the CO_2 emission in Laos's transport sector in BAU and countermeasure scenarios. As seen in the energy consumption results (Figure 3), CO_2 emission in transport sector shows the same trend. Due to increasing energy demand and high fossil fuel consumption, resulting CO_2 emission in BAU scenario will increase from 600 Gg CO_2 in 2014 to 800 Gg CO_2 in 2030, with a total growth rate of 65 %. Thereafter, CO_2 emission in BAU will sharply increase to 1,400 Gg CO_2 in 2050, with a remarkable total growth rate of 184 %.
Adopting the countermeasures, on the other hand, will result in noticeable decrease of CO_2 emission, especially due to the mitigation measures plus carbon tax and subsidy. However, the carbon tax policy alone will not mitigate CO_2 emission significantly. The reason might be that in the short-term, the public transport will not improve much, and most of citizens will still travel by their own private vehicles.

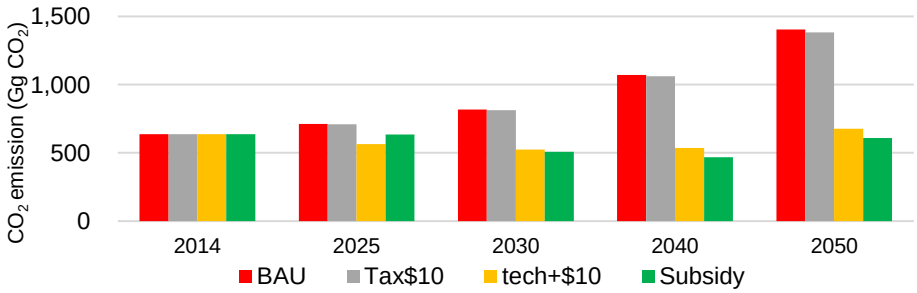

Figure 5: Comparison of CO_2 emission from BAU and countermeasures scenarios

The CO_2 mitigation countermeasure of extenuation technology plus carbon tax will result in decline of CO_2 emission from 800 Gg CO_2 in BAU scenario to around 500 Gg CO_2 in 2030, with the reduction accounting for 36 %; and in 2050, the emission will noteworthily drop from 1,400 Gg CO_2, in BAU scenario to about 680 Gg CO_2, the reduction amount being 720 Gg CO_2, accounting for 52 %.
Among all countermeasure scenarios, the subsidy policy will lead to the most significant fall in CO_2 emission, particularly during 2030 to 2050. Comparing to the BAU, the emission in subsidy scenario will go down as follows: from 800 Gg CO_2 to 500 Gg CO_2, accounting for 38 % drop, in 2030; from 1,000 Gg CO_2 to 470 Gg

CO_2, with reduction amount of 530 Gg CO_2, accounting for 56 % drop, in 2040; from 1,400 Gg CO_2 to 600 Gg CO_2, accounting for 57 % drop and an amount of reduction around 800 Gg CO_2, in 2050.

4. Conclusion

This paper analyses the CO_2 mitigation potential in the transport sector for Laos by assessing the effectiveness of certain policy packets/countermeasures (CMs). The model results of BAU scenario show the total energy consumption will increase in 2050 by 123 %. By introducing EV and biofuels exogenously with carbon tax or subsidy, it is observed that the final energy consumption will gradually reduce in the long-term. GDP will gradually decrease with a loss of 1.9 % by 2050, in case of the countermeasures scenario comprising EV and biofuels plus carbon tax and subsidy policy. In BAU scenario, CO_2 emission will increase remarkably with a growth rate of 184 %. EV and biofuel plus carbon tax will result in 56.7 % decline of CO_2 emission in 2050. The subsidy policy will lead to the greatest fall of CO_2 emission. In sum, introduction of carbon tax alone in transport sector will not influence household behavior for energy consumption in both short-term and long-term, resulting in no impact on CO_2 emission. This carbon price rate may not be enough to replace the conventional vehicle by EV, so higher carbon price should be analyzed for future analysis. Nevertheless, applying mitigation actions (EV and biofuel) plus carbon tax, and subsidy countermeasures can be a significant driver for influencing final energy consumption and CO_2 emission reduction. But introducing mitigation countermeasures, except for carbon tax, will result in a gradual decline of the GDP growth in the long-term.

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