Title : **Enhancing efficiency and renewable energy technology policy complementarity in mitigating climate change**

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1. Summary

Reducing anthropogenic greenhouse gas (GHG) emissions , globally, is a critical element in limiting the impacts of global warming. Specifically, reducing GHG emissions associated with energy production and end-use are a major component of any strategy addressing climate change mitigation. As such, improving energy efficiency of world economics as well as the scale-up of renewable energy in energy supply mix are considered fundamental to achieve the global energy transition to low carbon economy. However, in many of previous studies dealing with energy and climate policies, policymakers are often assumed to choose either energy efficiency improvement (EEI) or RenE technologies to address climate change challenges separately. Economic theory suggest that EEI and RenE could have opposite force on each other's growth rates, in other words, substitution effect predominates the complementarity effect. As a priori, larger scale renewable energy supply may hinder or delay the improvement of energy efficiency in final demand sectors (industry, agriculture , residential, tertiary and transport) as climate related energy supply constrain would be relaxed. Likewise, enhanced energy efficiency of end use may reduce, at least delay the requirement of new energy resources including RET development. Yet another possibility is EEI and RenE may play positive interaction between each other, i.e. enhanced EEI may help accelerate the deployment of RenN at larger scale. Hence it is appropriate to combine both solutions without necessarily discriminative development target in each of the two.

This paper examines the dynamic interaction between energy efficiency and renewable energy policies in a global macroeconomic frameworks in conformity with the long term climate mitigation targets , based on the latest EMF-27 runs of integrated modelling assessment of climate policies across different regions in the world. Both global and regional consequences are investigated. Our analysis shows that relying on a single technical portfolio (either EEI or RenE) will make larger impacts of global climate policy on world economic growth, whereas an integrative approach, which combine energy efficiency and renewable energy scale-up over the next decades, will permit significant reduction of costs to implementing climate policies in the world, in particular it will attenuate the incremental costs (as a result of carbon tax on fossil fuel consumption) the emerging and developing countries. More specifically, energy efficiency improvement plays a crucial role in accelerating global GDP growth and scaling up renewable energy.

Two major lessons may be learnt from the the modelling outcome. First : theoretical prediction holds true for short term perspective and fails in terms of market share of RenE in total energy supply, it is found that EEI and RenE policies are actually complementary instead of substituting each other. Second: the positive interaction between EEI and RenE policies may lead to lower costs of GHG mitigation at both global and regional scale, it is particularly true in developing countries. These results have considerable policy implications in the global climate change research and negotiations.

2. Methodology and study framework design

We use IMALCIM-r model (a multi-regional and multi-sectoral hybrid CGE model) to investigate the EE and RenE technological change in a carbon constrained world. Besides

EEI and RenE development, we also take into account nuclear and CCS technology parameters into account in the modelling framework. specifically, CCS commercialisation will make negative emissions (biomass sequestration) technically feasible to achieve deeper carbon emissions mitigation in the longer term. Two sets of scenarios will be run, namely BAU cases runs (R3G1, R3G2, R3G6) and Policy cases runs --> RCP 3.7 W/m^2 (550 ppm COeq [1]) including 317, 318, 323 and 334 runs.

3. **Expected results and discussions**

a) interaction between EEI and RenE policies

Although the correlation and interaction between EEI and RenE is hardly discernible or as suggested by the theory (they act in opposite way) in the short term, faster EEI will actually result in higher proportion of RenE in primary energy supply (S317 > S 318 and S334>S323) in the longer term. RenE will increase faster during the first half of the century than the second period, suggesting that most RenE potentials, including the biomass sequestration (in 317 and 318 run), is likely to be tapped in the next forty years to achieve the climate stabilization target. Note that Biomass energy may play a crucial role in global energy supply decarbonization (see for example Bibas and Méjean 2012).

b) GDP growth losses

It is found that 318 and 334 runs will permit higher global economic growth compared with 317 and 323 runs. This confirms again the role of EEI in mitigating negative effect of climate policies on the long term economic growth. It is clearly shown that slow EEI and delayed deployment of RenE supply will lead the world to systematic economic growth loss throughout the first half the century. Combined EEI and RenE (318 ALL tech scenario) would lead to minimize the transition costs of climate policy (the highest growth rate). 318 All Tech run has persist positive effect since the global economic growth rate would be higher than the BAU case.

4. **Preliminary conclusions**

This study used numerical simulation to test the theoretical prediction of the relationship between EEI and RenE policies. Our simulation shows that a unified theoretical framework should integrate the temporal dimension. EEI and RenE has opposite effect on each other in the short term. i.e. EEI may slightly reduce the proportion of RenE in total energy supply. However, higher EEI will encourage the penetration of RenE while slowing down its growth rates (better energy efficiency reduce the final energy demand and thus mitigate the increase in energy supply). More specifically, we found that integrative energy policy (combined EEI and RenE portfolio) will significantly reduce the transition costs of climate mitigation policies at both global and regional levels.

5. **references**

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1 See EMF-27 protocol. p.7 : “A forcing of 3.7 W/m2 corresponds to a 550 ppm CO2 equivalent concentration…”