The Path to Carbon Neutrality: A Time Series Approach

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INTRODUCTION

Carbon neutrality is the United Nation's most urgent mission, but lack of data, evaluation criteria and techniques presents a challenge. The global energy crisis because of COVID-19 and Ukraine War has complicated carbon emission data analysis. Policymakers have failed to meet established carbon reduction goals.

We adopt CO2 emission and sink data released in November 2022 and introduce new models to recalculate path.

Our research builds most up-to-date dynamic global pathway to achieve carbon neutrality in 2050.

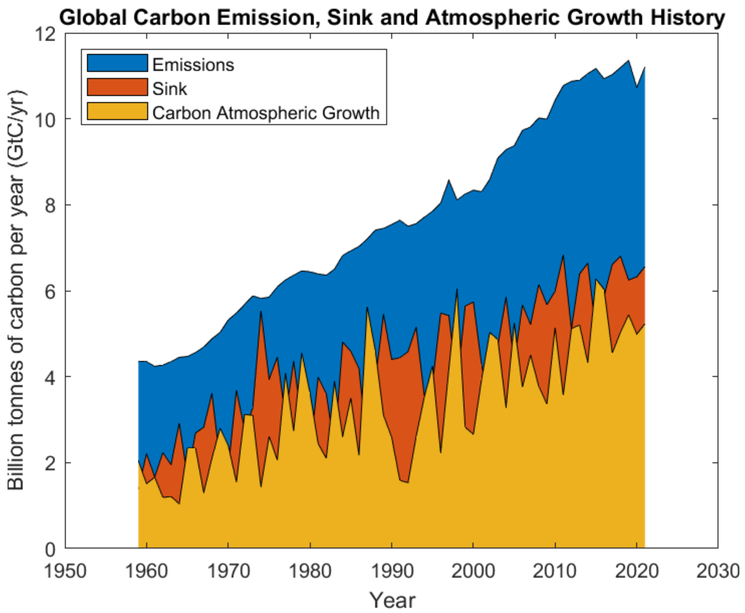


Fig. 1 Global CO2 emission, sink and atmospheric growth

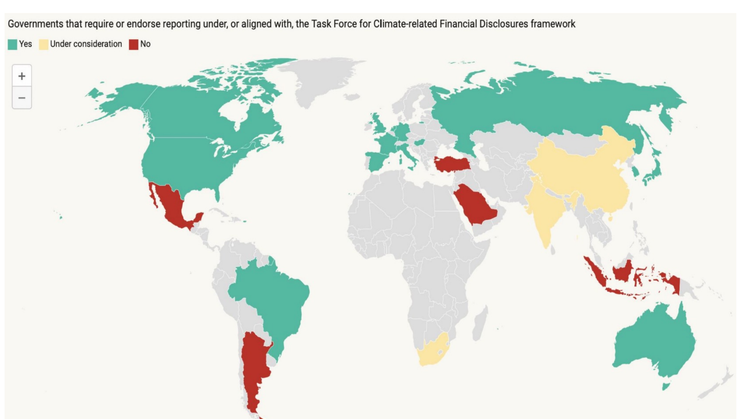


Fig. 2 Governments that introduce TCFD-aligned Disclosures

The steady growth in global regulations on Task Force on Climate-related Financial Disclosures (TCFD) marks the importance of carbon neutrality research

METHODS

- Use **Time-Varying Parameter Vector Autoregressions (TVP-VAR)**[1][2] model and **Monte-Carlo simulation** to monitor the dynamics of net-zero emission roadmap.
- Use **Long Short-term Memory** (**LSTM**) networks to simulate pattern from a deep learning perspective

$$A\mathbf{y}_t = F_1\mathbf{y}_{t-1} + \cdots + F_s\mathbf{y}_{t-s} + \mathbf{u}_t, \quad t = s+1, \ldots, n$$

$$\mathbf{u}_t \sim N(\mathbf{0}, \Sigma^T\Sigma)$$

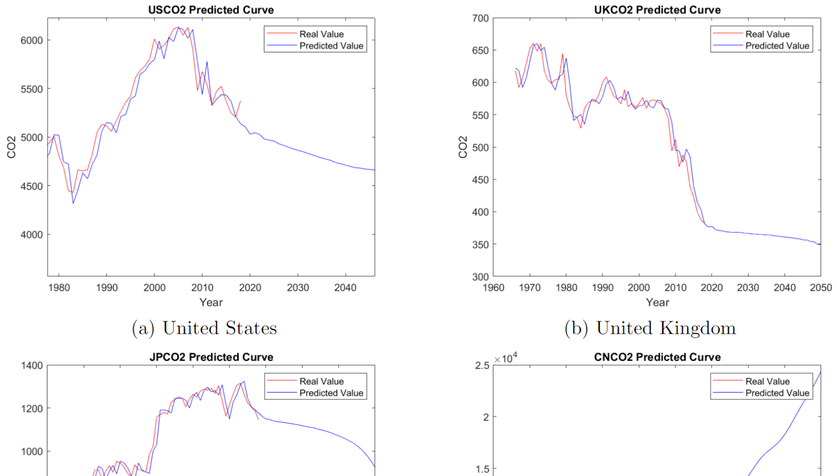
$$\Sigma = \mathrm{diag}(\sigma_1, \ldots, \sigma_k)$$

$$\hat{y}_t = X_t\hat{\beta}_t$$

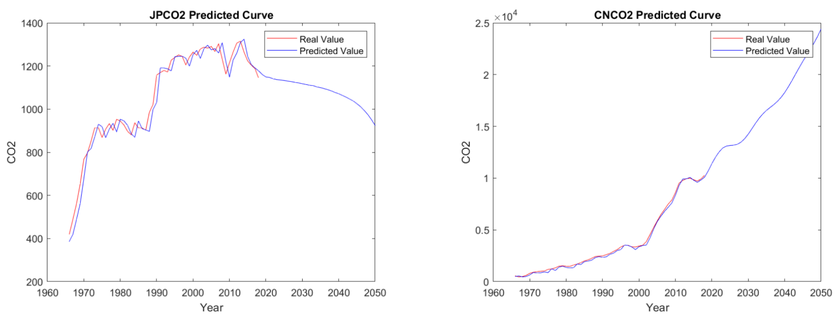
Tab. 1 Global Neutrality Target on UNCCC [3]

Country	2020 Target at UNCCC	2050 Global Neutrality Target
China	45% less than 2005	50% less than 2005
United States	4% less than 1990	80% less than 1990
European Union (including UK)	30% less than 1990	80% less than 1990
Japan	25% less than 1990	80% less than 1990

Apply TVP-VAR, Monte-Carlo and LSTM after setting carbon emission target according to UNCCC plan



(a) United States (b) United Kingdom



(c) Japan (d) China

Fig. 3 CO2 emission prediction curve

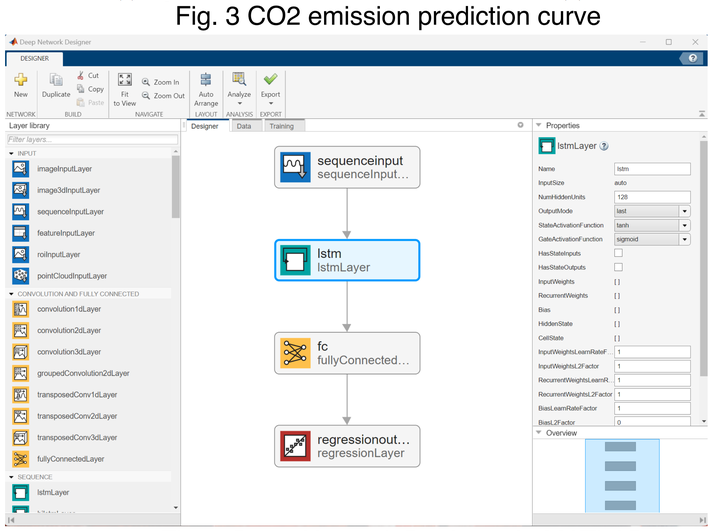


Fig. 4 Deep Network Designer in MATLAB

RESULTS

- **TVP-VAR & Monte-Carlo: all Geweke statistics < 2**
- **LSTM model: normalized RMSE as small as 0.06**

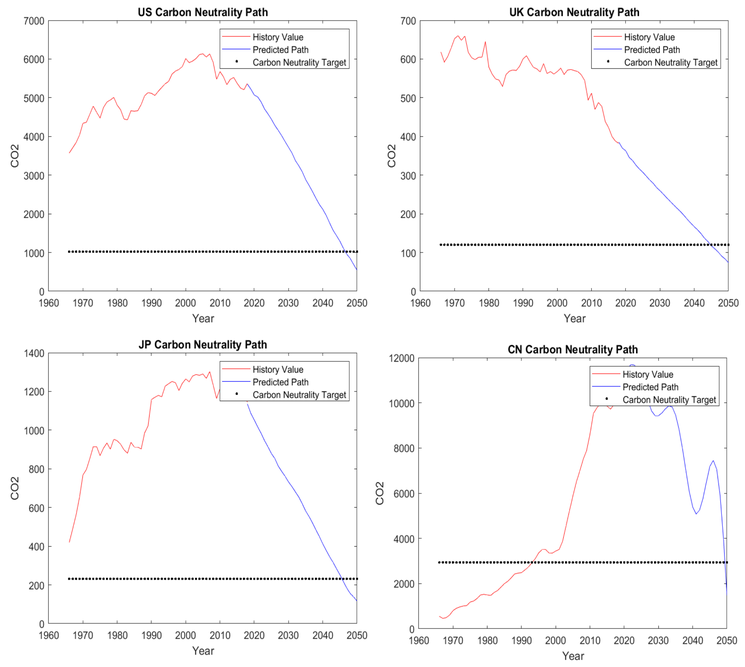


Fig. 5 Carbon Neutrality Path Simulation

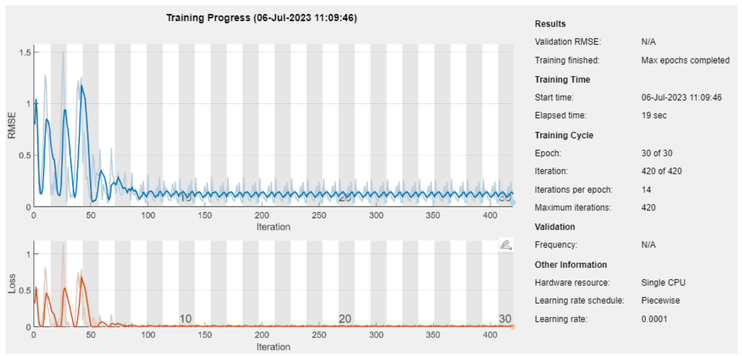


Fig. 6 LSTM Training Result

CONCLUSIONS

It is around **5%** success rate for US, UK, Japan and China to achieve their carbon neutrality goals by 2050 under current conditions, shown by TVP-VAR model coupled with Monte Carlo simulations

- **Realizing 2050 carbon neutrality as set by UNCCC plan is achievable and promising**
- **Global collaboration on carbon reduction is a must**

REFERENCES

[1] Primiceri, G. E. , "Time Varying Structural Vector Autoregressions and Monetary Policy," The Review of economic studies; The Review of Economic Studies 72(3), 821-852 (2005).

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[3] Leggett, J. A., [A U.S.-Centric Chronology of the United Nations Framework Convention on Climate Change], Congressional Research Service, Washington, D.C (2018).