Research Proposal

A Quantum Bayesian Adapted Model for Assessing Environmental Impacts of the Global Economy

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1 Introduction:

Rapid globalisation in the past decade has led growth in trade to quickly outpace growth in real-adjusted gross domestic product (GDP) across the globe. As such, the impact of a nation's consumption has aggravated by an unprecedented magnitude; value chains of most products span many countries with rising pressures of economic activity on global ecosystems constituting a growing need for effective policy. Measurements for quantifying and analysing the scale of environmental shocks across trade networks have largely focused on embedded emissions, which in this project will be represented in a multi-regional input-output model (MRIO), extended with environmental coefficients to appraise corresponding value chains. Ultimately, with the usage of both a Bayesian probability and quantum-agent based model, we wish to provide a simulated pseudo-economy for which environmental effects (embodied CO2) can be appropriately measured for various scenarios. This project aims to provide empirical support for global policies to push for the sustainable management of supply chains, as well as in the emerging field of quantum economics.

1.1 Intellectual Merit

The intellectual merit of this research stems from past research, notably from Tukker et. al. 2018 and Wiedmann et. al. 2007, which had previously studied the potential of MRIO matrices in producing effective policy measures, such as in EU carbon regulations and China development plans. This project would thus contribute significantly to the field of environmental economics and developmental economics by integrating an innovative technique – the mesh of MRIO models, Bayesian probability, and Quantum agent-based methods – to enhance traditional frameworks and thus provide a more robust analytical tool for quantifying the environmental impacts of global trade networks.

1.2 Broader Impacts

The goal of this research is to provide policymakers with empirically grounded insight into the nature of environmental externalities at play with current regulatory measures enforced by the global economy. We hope that with the results, we can establish a good projection of how sustainable trade practices may have a direct impact on the global environment – be that ecologically, socially, or economically. We may also identify high-impact sectors and/or products, which can guide policymakers to make more specific regulations to incentivise sustainable practices and promote environmental responsibility across the globe.

2 Specific Project Goals and Measurements:

1. **Efficacy of the MRIO model under Bayesian or quantum methods**
   Recognizing that trade networks and corresponding environmental impacts are inherently complex and uncertain, we wish to use Bayesian methods to enable the MRIO model to update its predictions as final demand (a proxy for market activities) is stimulated. The usage of the Bayesian model creates a probabilistic model that would be our first method to quantify this uncertainty associated with economic assumptions (such as rational consumers, political trade networks, etc.). Similarly, we wish to build off of this with a quantum-agent based model to compare the efficacy of utilizing quantum-based principles in accounting for economic uncertainties. Quatum computing offers the potential to process large dataset more efficiently than classical methods, which could potentially make this task more feasible. Additionally, we hope to create a quantum-agent based environment to simulate various agents in a pseudo-economy; this is similar to the Bayesian approach as it also captures probabilistic natures of agent behavior, but we wish to see if we can exploit quantum superposition and entanglement to provide deeper insights.

2. **Measurements and Methodology**
   Using historical IO data from the Eora26 database, we hope to firstly establish baseline consumption patterns, then develop multiple scenarios representing different factors influencing final market demand, such as policy changes, technological advancements, consumer behavior (some of these changes have already been studied in literature; we may be able to apply directly). From this data, we will create a Multi-Regional Input-Output model, from which we can establish a corresponding environmental coefficient matrix in order to apply formulas to calculate the total environmental impact. This will be done with the Leontief inverse from the technical coefficients matrix.

   (a) We will largely be calculating the embodied CO2 emissions associated with each scenario, also taking into account the accuracy (percent error) of predictions made with the Bayesian and Quantum methods.

3 Specific Responsibilities of Group Members:

Megan Zhang
Clean the dataset, create the MRIO model for various years (python), graphically organize in R/python. Conduct necessary technical coefficient calculations for the simulation prep.

SECOND PERSON (TBD)

- Help code.

4 Potential Pitfalls and Alternative Strategies:

1. Uncertainty in Behavioral Assumptions

   Potential Challenge: The assumptions about market behavior in the quantum-agent model may not accurately reflect real world dynamics, which may thus mislead.

   Solution: Conduct an extensive sensitivity analysis (post-model?) to explore how different assumptions can affect model outcomes. We still need to make sure the original MRIO model is sound before doing this.

2. Model complexity

   Potential Challenge: The integration of a large-scale MRIO model in conjunction with Bayesian and quantum-agent based simulations may result in complex models that are challenging to manage and interpret without missing some externalities.

   Solution: Adopt some aggregations (i.e. regional) to break down the overall model into smaller, manageable components.

5 Proposed Timeline:

5.1 Experimental Timeline

Mid-September: Formal Project Proposal

Task: Complete project proposal

Goal: Complete the project proposal.

Mid-December: Interim Benchmark 1: Completion of probabilistic scenarios to run

Task: From past Literature and raw analysis on historical data in the MRIO table from the Eora26 dataset, decipher patterns that may be necessary to quantify.

Objective: Quantify economic assumptions to prepare for the Bayesian probability model and the quantum agents.

Goal: Create and prepare probabilistic scenarios. Literature review should be finished accordingly too.

Mid-March: Interim Benchmark 2:

Task: Simulate with Bayesian/Quantum agent based models.

Objective: Code.

Goal: Find out the validity of results and compare the two methods. Analyse any discrepancies and long-term patterns.

End of May: Final Benchmark: Complete Experiment and Prepare for TjStar

Task: Finish final preparations for the TjStar presentation.

Objective: Make a cool poster and make sure everyone thinks the project is cool.

Goal: Results exist.

5.2 Research Paper Timeline

Mid-December: First Draft of Introduction and Background

Task: Gather information from previous literature on the possible methodologies previously in use for quantum agents in a pseudo-economy. Consider topics: MRIO in embodied trade networks, embedded CO2 measurements, Bayesian economics, quantum-agent based modeling.

Goal: From the above sources, create a holistic background.

Mid-March: First Draft of Methods and Preliminary Results

Task: Properly compile results and necessary graphs/visualisations from all preceding steps.

Goal: Ensure that the MRIO model is sound for a few decades and provide a visualisation on such global patterns. Utilise such patterns to fit into the Bayesian probability and Quantum models. If appropriate, modify the parameters of the agents as a preliminary sensitivity analysis.

End of May: Final Research Paper

Task: Finalize paper and presentation of results and relevance to the scientific community.

Goal: Don't lose sanity.

6 Citations

(a) Tukker, A., Giljum, S., & Wood, R. (2018). Recent progress in assessment of resource efficiency and environmental impacts embodied in trade: An introduction to this special issue. *Journal of Industrial Ecology, 22*(3), 489-501. https://doi.org/10.1111/jiec.12780

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- Lenzen, M., Moran, D., Kanemoto, K., & Geschke, A. (2013). Building Eora: A global multi-region input–output database at high country and sector resolution. *Economic Systems Research, 25*(1), 20-49. https://doi.org/10.1080/09535314.2013.769010
  - for mechanics of the dataset