Constructing a Dynamic Budget Impact Model: An AI Pre-Training Approach for a New Parkinson's Disease Drug

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INTRODUCTION

Taiwan's aging population and rising chronic disease burden are putting growing pressure on National Health Insurance (NHI), especially with the inclusion of high-cost innovative drugs. Existing Budget Impact Analyses (BIA) focus mainly on short-term affordability, often neglecting indirect costs, long-term effects, and policy dynamics. Meanwhile, critical shortages in the healthcare workforce threaten system sustainability. Artificial intelligence (AI) offers a promising solution, enhancing analytic accuracy and enabling responsive policymaking. This study integrates AI into a dynamic BIA model to support comprehensive financial and policy evaluation for new drug reimbursement under Taiwan's NHI.

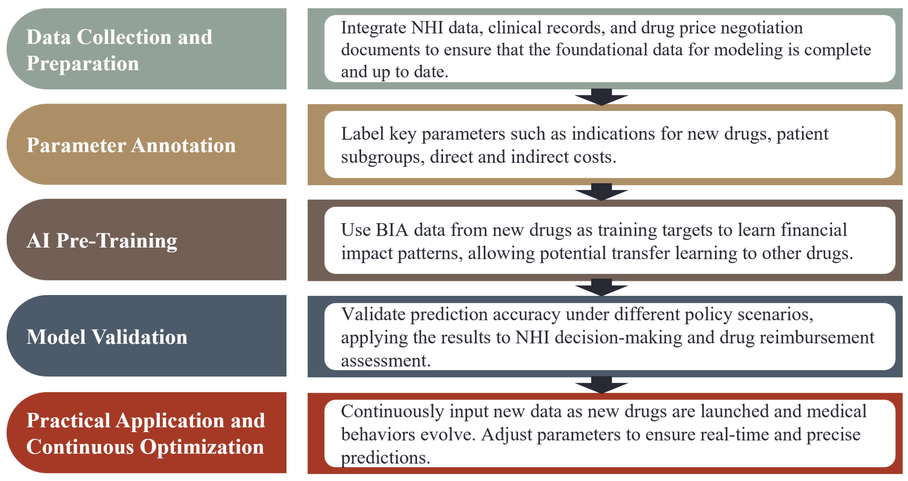
OBJECTIVE

- Develop an AI-driven dynamic Budget Impact Analysis (BIA) model using a new Parkinson's disease drug as a case study.
- Integrate real-world data and enable dynamic parameter updates for real-time financial and societal impact assessments.
- Validate that AI-assisted BIA improves predictive accuracy and informs policy decisions on drug reimbursement and NHI sustainability.

METHOD

This study constructs a dynamic BIA model supported by AI pre-training, integrating real-world data and applying it to Taiwan's NHI system for new drug reimbursement.

Model Design: Building the NHI BIA Model through AI Pre-Training



Model Features:

- Dynamic Parameters: Real-time updates of target population, drug price, and adoption/substitution rates via NHI and real-world data. Machine learning predicts yearly trends.
- Comprehensive Costing: Captures direct medical costs and indirect costs such as productivity loss, caregiving time, and released healthcare workforce.
- Sensitivity & Marginal Analysis: Tests multiple policy and market scenarios. Calculates marginal budget impact per additional patient.

AI Module:

- Continuously integrates real-time NHI and policy data
- Pre-trained on high-cost drug simulations; adaptable to other therapies.
- Automates accurate, real-time financial impact estimation.

Application:

- Supports NHI reimbursement decision-making.
- Facilitates cross-sectoral resource integration (e.g., long-term care).
- Enables scenario-based value-based payment simulation.

RESULTS

Model Validation and Scenario:

- Parkinson's disease (PD) chosen as a case to validate the dynamic BIA model due to its high prevalence, significant medical costs (NT$631,080/year per patient), and detailed local data.
- New drug "Drug N" (extended-release levodopa + carbidopa) modeled under NHI reimbursement conditions focusing on patients with motor fluctuations.
- Five-year simulation period: 2025–2030.

Target Population and Penetration Rates:

- PD population growing from ~85,400 (2024) to ~95,400 (2029).
- COMT inhibitor users ~13.5% of PD patients; Drug N adoption projected to grow from 5.5% penetration (2024) to 20.3% (2029).
- Substitution rates for existing drugs (Comtan, Stalevo) gradually increase, reflecting realistic market shifts.

Five-Year Budget Impact Overview (NT$)

Year	Drug N Users	New Therapy Cost	Therapy Replacement Saving	Indirect Cost Savings	Net NHI Impact
2025	1,022	61.7M	21.9M	27.7M	12.1M
2026	1,411	87.6M	30.2M	39.2M	18.3M
2027	1,814	114.5M	38.9M	50.3M	25.3M
2028	2,232	137.4M	47.5M	61.9M	28.0M
2029	2,614	147.9M	55.7M	72.5M	19.7M

- Net budget impact grows moderately despite rising user number and drug cost, buffered by replacement and indirect savings.

Validation Results of AI-Trained Dynamic BIA Model (NT$)

Year	Research BIA Model	AI Predicted Value	Absolute Error
2025	12,100,076	12,098,179	1,897
2026	18,252,865	18,245,564	7,301
2027	25,292,322	25,262,582	29,740
2028	27,982,843	27,836,908	145,935
2029	19,741,794	19,712,010	29,784
Mean Absolute Error (MAE)			42,932
Coefficient of Determination (R^2)			0.99985

- XGBoost AI model trained on budget simulation data predicted outcomes with near-perfect accuracy:
  - R^2 = 0.99985 (almost perfect fit)
  - Mean absolute error: NT$42,932
- Confirms AI module's feasibility for automating dynamic BIA predictions.

Policy Scenario Simulation & Sensitivity Analysis

Scenario	Key Assumptions	5-Year Budget Impact (NT$)	Key Insight
Baseline	Standard values	103.4M	Reference case
Scenario 1	+10% penetration, −10% savings	107.5M	Risk of overexpansion with limited value
Scenario 2	−5% price, +10% penetration	52.1M	Financially efficient, but may hinder innovation
Scenario 3	+5% penetration, +10% savings	50.8M	Most sustainable and value-driven outcome

CONCLUSIONS

AI for Sustainable NHI Policy

Four key policy recommendations for Taiwan's NHI:

- Use dynamic BIA to balance drug price negotiations and avoid market withdrawals.
- Adopt value-based payment models with real-world evidence and risk-sharing agreements.
- Establish cross-department data-sharing and AI-driven real-time BIA platforms.
- Promote AI integration with unified data governance and training programs.

Future work should expand local data integration, cover more diseases, combine long-term economic evaluations, refine negotiation models, and address technical and institutional challenges for smart health governance.

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