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Predicting Tax Treaty Formation Using Machine Learning: Implications for Parliamentary Practice

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Content

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Tax treaty formation

- Main goals of tax treaties:
  - Boost **trade and investment** by eliminating tax barriers;
  - Fight tax evasion and double non-taxation with **anti-avoidance** measures;
  - **Exchange of information**, a primary focus of new tax treaties.
- **Complex decision-making process** precedes tax treaty formation:
  - Historically driven by **"chess-games between superpowers", key persons' decisions, and corporate lobbyism**;
  - **Policy diffusion** and other factors may influence tax treaty formation.
- Double tax treaty probability can be predicted using machine learning approach.
- Highly relevant for policymakers:
  - Identifies advantageous treaties to pursue given **limited capacity of negotiators**;
  - Helps **assess risk of FDI diversion** to neighboring jurisdictions;
  - Aids in understanding level playing field for multinational firms in foreign markets.

Literature – tax treaty formation

Economic factors:

- Personal tax rates, non-resident withholding tax rates on dividends and interest
- FDI stock, symmetric allocation of FDI
- Transfer price, auditing costs, production costs
- Revenue sharing differences

Governance and policy factors:

- Tax haven bargaining power
- Good governance
- Experience in entering into tax treaties

International relations factors:

- Spatial spillovers and dependence in tax treaty formation
- Export-product competitors
- Power asymmetries between signatories
- Developed countries compensating developing countries' tax base losses through foreign aid

Other factors:

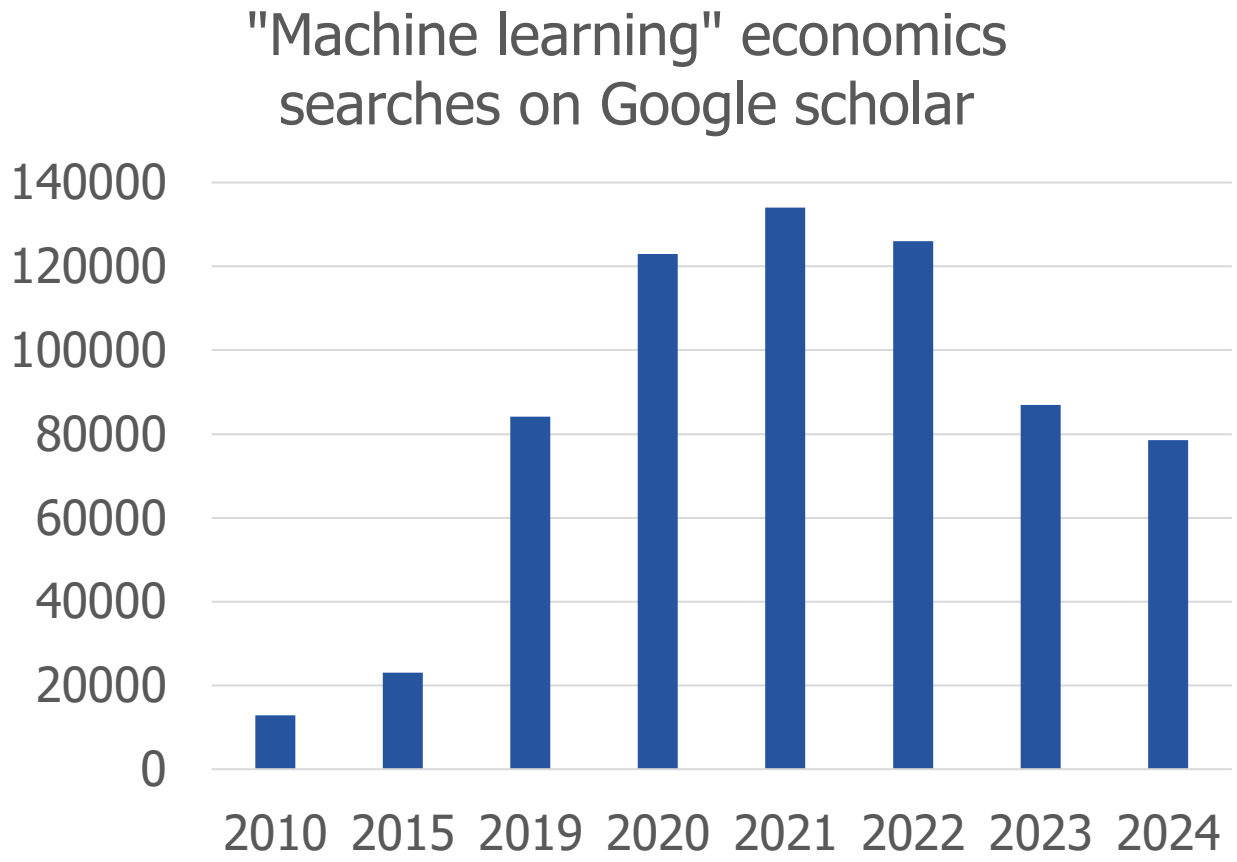
- Common language
- Information sharing, tax audit, and revenue sharing agreements

Withholding tax rates:

- Positive relationship with withholding tax rates negotiated in past tax treaties
- Spatial dependence of dividends withholding tax rates
- Increase in withholding tax rates with asymmetric FDI activities

Machine learning in economics

- Increased application in recent years.
- Various areas of economics such as energy economics, growth economics, crypto economics, urban economics, and taxation.
- Modeling **complex and flexible relationships**.
- Uncovering **generalizable patterns** and finding functions with high **out-of-sample predictive power**, which is important for policy makers.
- Limited prior theoretical assumptions or major assumptions on variable distribution.

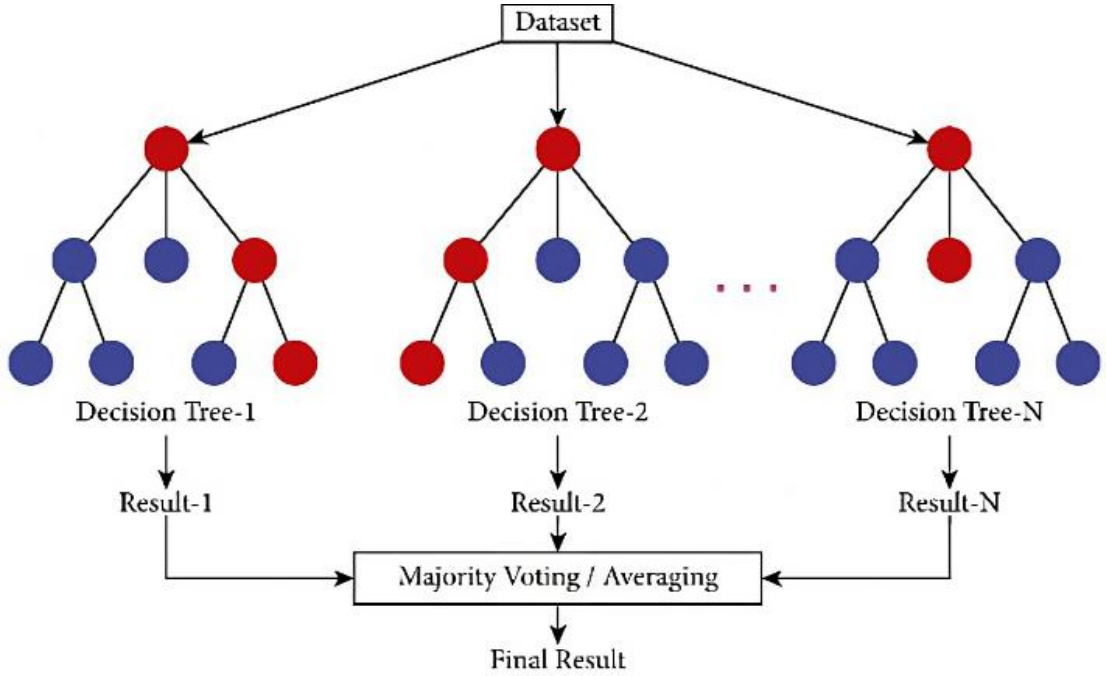


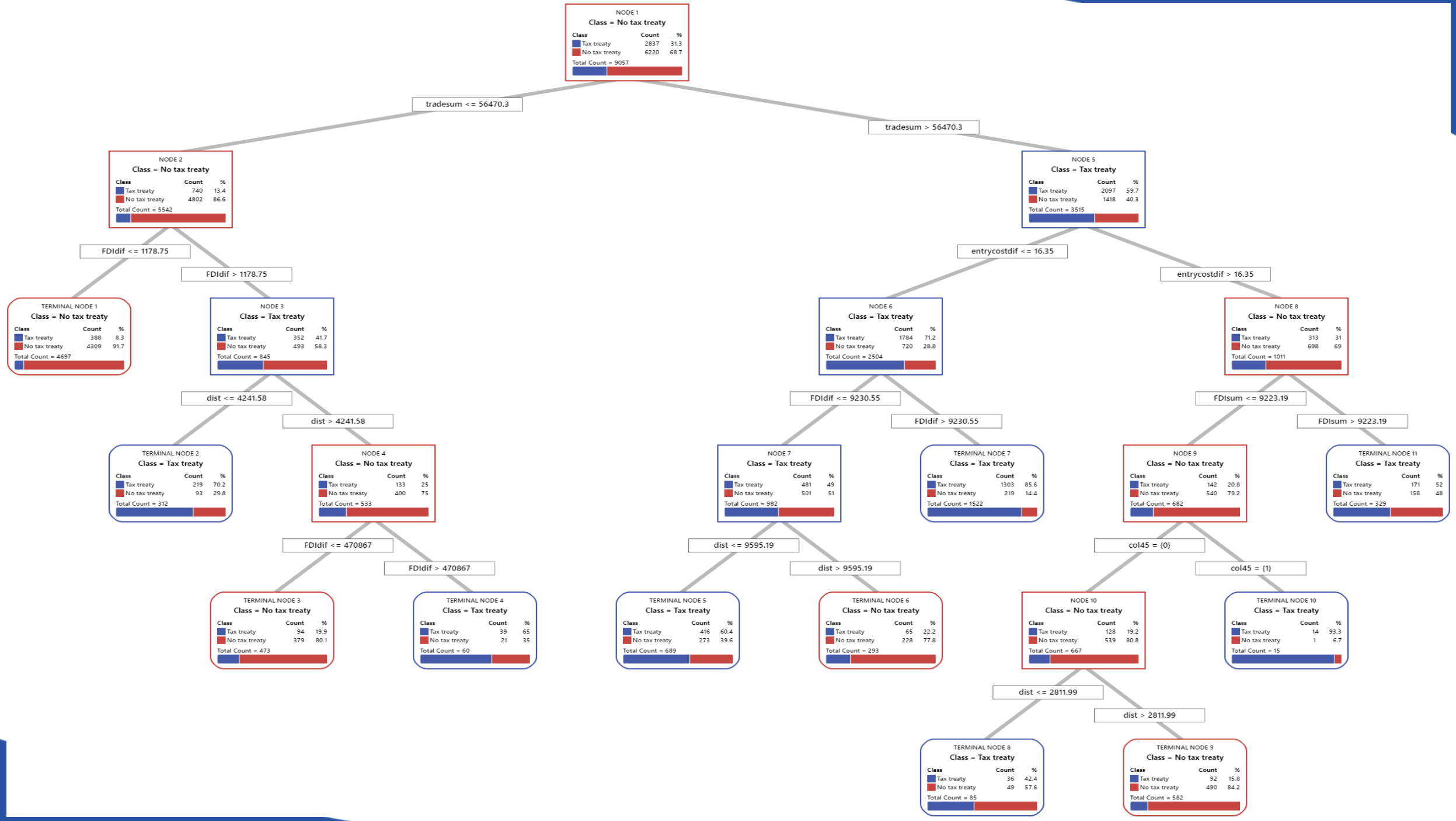
Methodology and data

- **Binary classification problem**: country pairs as "having tax treaties" or "not having tax treaties".
- c_ml_stata_cv command, Stata/Python integration, scikit-learn API.
- Supervised machine learning algorithms: classification tree, random forest, boosting, regularized multinomial, nearest neighbor, neural network, naive Bayes, support vector machine, and standard multinomial algorithms.
- Classification error rate on the test data, sensitivity, precision, specificity, F1-score, and area-under-the-curve.
- Two periods: 2018 for training the machine and 2019 for testing it.
- 2800 country pairs with tax treaties and 6200 without tax treaties.
- 29 gravity features constructed as bilateral variables.

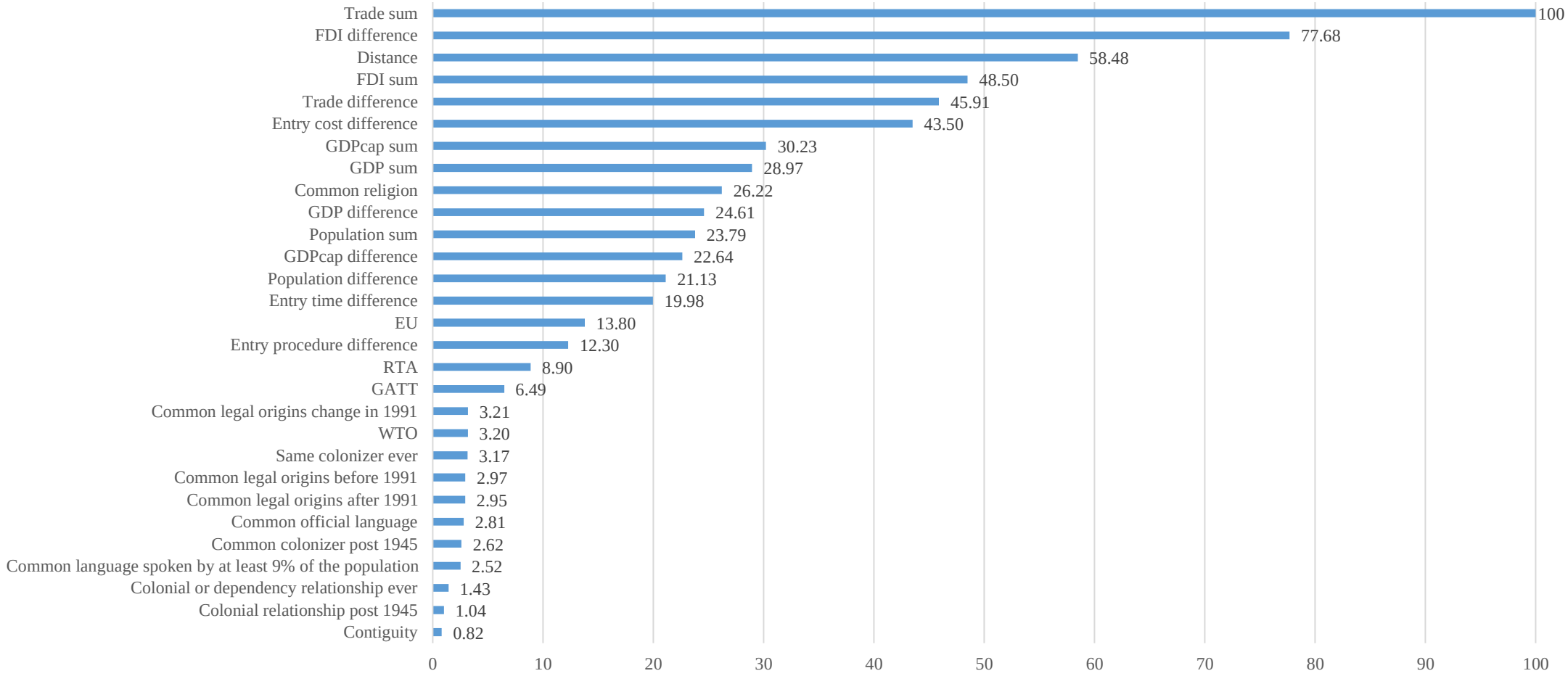
Algorithm selection

- The selection of the most accurate algorithm is based on the testing classification error rate, and the **random forest** algorithm has the lowest rate (0.057).
- The random forest algorithm outperforms other algorithms according to all the evaluation metrics.
- Both the random forest algorithm and the classification tree algorithm exhibit a zero training classification error rate and the lowest two testing classification error rates.
- A specific classification tree with 11 nodes drawn using the CART® Classification of the Minitab statistics package.

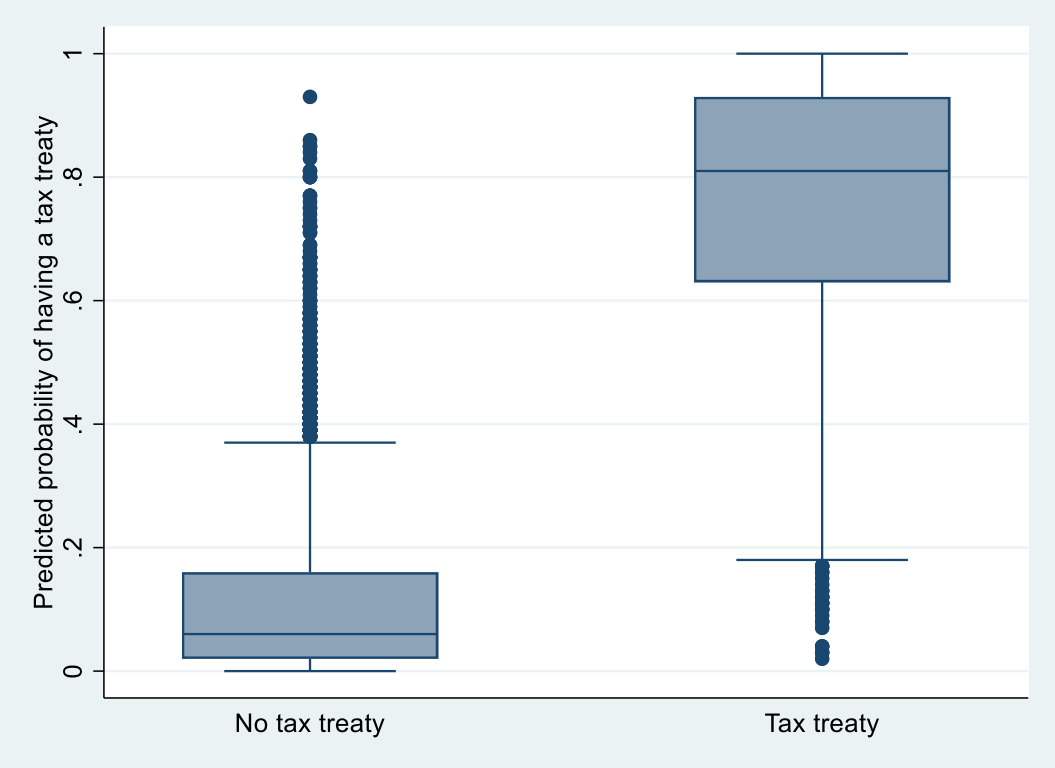


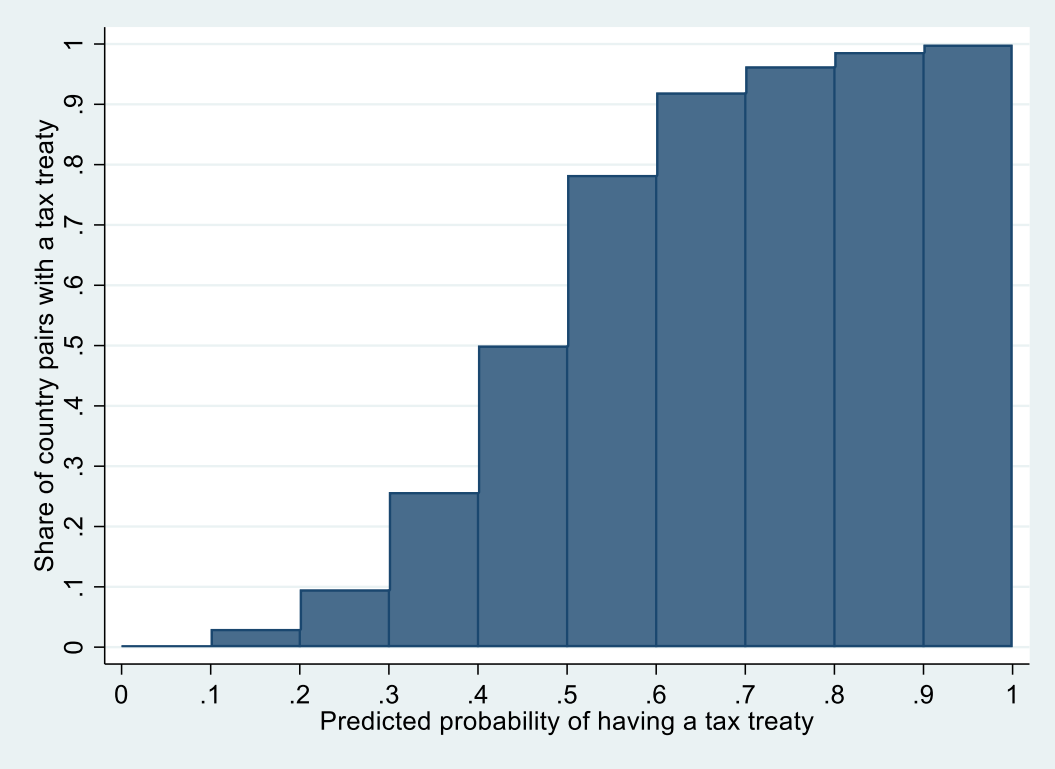

NODE 1
Class = No tax treaty
Class Count %
Tax treaty 2837 31.3
No tax treaty 6220 68.7
Total Count = 9057
tradesum <= 56470.3
tradesum > 56470.3
NODE 2
Class = No tax treaty
Class Count %
Tax treaty 740 13.4
No tax treaty 4802 86.6
Total Count = 5542
NODE 5
Class = Tax treaty
Class Count %
Tax treaty 2097 59.7
No tax treaty 1418 40.3
Total Count = 3515
FDIdif <= 1178.75
FDIdif > 1178.75
entrycostdif <= 16.35
entrycostdif > 16.35
TERMINAL NODE 1
Class = No tax treaty
Class Count %
Tax treaty 388 8.3
No tax treaty 4309 91.7
Total Count = 4697
NODE 3
Class = Tax treaty
Class Count %
Tax treaty 352 41.7
No tax treaty 493 58.3
Total Count = 845
NODE 6
Class = Tax treaty
Class Count %
Tax treaty 1784 71.2
No tax treaty 720 28.8
Total Count = 2504
NODE 8
Class = No tax treaty
Class Count %
Tax treaty 313 31
No tax treaty 698 69
Total Count = 1011
dist <= 4241.58
dist > 4241.58
FDIdif <= 9230.55
FDIdif > 9230.55
FDIsum <= 9223.19
FDIsum > 9223.19
TERMINAL NODE 2
Class = Tax treaty
Class Count %
Tax treaty 219 70.2
No tax treaty 93 29.8
Total Count = 312
NODE 4
Class = No tax treaty
Class Count %
Tax treaty 133 25
No tax treaty 400 75
Total Count = 533
NODE 7
Class = Tax treaty
Class Count %
Tax treaty 481 49
No tax treaty 501 51
Total Count = 982
TERMINAL NODE 7
Class = Tax treaty
Class Count %
Tax treaty 1303 85.6
No tax treaty 219 14.4
Total Count = 1522
NODE 9
Class = No tax treaty
Class Count %
Tax treaty 142 20.8
No tax treaty 540 79.2
Total Count = 682
TERMINAL NODE 11
Class = Tax treaty
Class Count %
Tax treaty 171 52
No tax treaty 158 48
Total Count = 329
FDIdif <= 470867
FDIdif > 470867
dist <= 9595.19
dist > 9595.19
col45 = {0}
col45 = {1}
TERMINAL NODE 3
Class = No tax treaty
Class Count %
Tax treaty 94 19.9
No tax treaty 379 80.1
Total Count = 473
TERMINAL NODE 4
Class = Tax treaty
Class Count %
Tax treaty 39 65
No tax treaty 21 35
Total Count = 60
TERMINAL NODE 5
Class = Tax treaty
Class Count %
Tax treaty 416 60.4
No tax treaty 273 39.6
Total Count = 689
TERMINAL NODE 6
Class = No tax treaty
Class Count %
Tax treaty 65 22.2
No tax treaty 228 77.8
Total Count = 293
NODE 10
Class = No tax treaty
Class Count %
Tax treaty 128 19.2
No tax treaty 539 80.8
Total Count = 667
TERMINAL NODE 10
Class = Tax treaty
Class Count %
Tax treaty 14 93.3
No tax treaty 1 6.7
Total Count = 15
dist <= 2811.99
dist > 2811.99
TERMINAL NODE 8
Class = Tax treaty
Class Count %
Tax treaty 36 42.4
No tax treaty 49 57.6
Total Count = 85
TERMINAL NODE 9
Class = No tax treaty
Class Count %
Tax treaty 92 15.8
No tax treaty 490 84.2
Total Count = 582

Relative variable importance (random forest)



Prediction accuracy





Tax treaty formation prediction

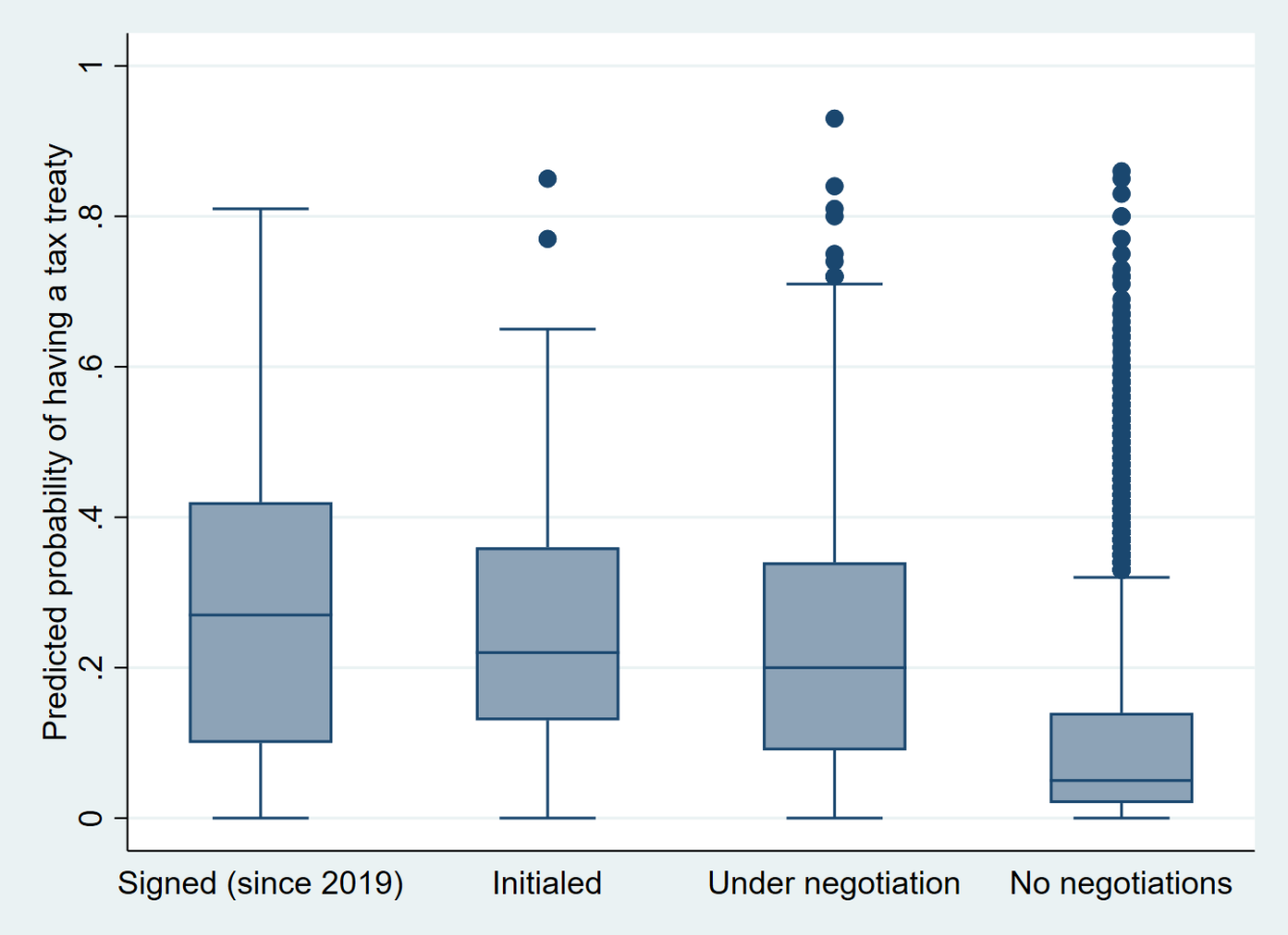
- **59 country pairs** likely to have tax treaties based on 2019 gravity features.
- Germany (9), Saudi Arabia (8), Brazil (7), Myanmar (7), and Hong Kong (6).
- 24 country pairs in negotiation process, 4 signed a tax treaty, 3 initialed a tax treaty, 6 signed or negotiating exchange of information agreement or transport tax treaty, and 3 terminated tax treaties.

Country/region A	Country/region B	Predicted probability of a tax treaty in 2019	Current status of a tax treaty in 2023 (IBFD, 2023; Orbitax, 2023)
Croatia	United States	0.62	Signed (December 2022)
Denmark	France	0.81	Signed (February 2022)
Brazil	United Kingdom	0.76	Signed (November 2022)
Brazil	Poland	0.67	Signed (September 2022)
Austria	Bangladesh	0.55	

Austria and Bangladesh Seek to Conclude Tax Treaty

May 1, 2024

Predicted probability vs actual status after 2019



Implications for parliaments

- Clear **guideline** on how machine learning algorithms can inform policymakers on treaty policy to follow.
- Policymakers in countries with missed opportunities for negotiation should take advantage of **potential treaties** to improve their treaty policy.
- **Neighboring countries** should check their existing treaty network and tax policy with respect to potential partners of their neighbors, given predicted treaties between other countries.
- Other potential applications:
  - Predictive analysis of policy outcomes
  - Economic forecasting
  - Analyzing public opinion
  - Resource allocation
  - Fraud detection
  - …

Thank you for your time.

Questions.