Forecasting Firearm Innovation: A Time Series Analysis of U.S. Patent Trends & Macroeconomic Influencers, 1820 - 2025

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Introduction

- Firearm innovation is tracked by aggregating the count of F41 patents per month
  - To model existing data, Naive, ARIMA, ARIMAX, and TAR time series models are used to forecast 10 years into the future
  - To identify the best economic indicators of innovation, we use count-specific regressions
- To understand the role that the U.S. Government/Military plays, individual analysis using an ARIMAX model is perfomed on "private" patents
- Case study of F41A17 safety arrangements to identify what indicators explains trends in this specific subclassification

Research Questions

- How has firearm innovation developed in the United States since 1820?
- In what area(s) has innovation taken place?
- How do we see the future in firearms?
- How do fluctuations in the United States economy affect arms development?
- Does U.S. government/military spending have an impact on firearm innovation?

Methods

Data

- USPTO: Firearm Patents (F41 classification)
- UN Comtrade API: U.S. code 93 exports
- Economic indicators:
  - Government expenditures (billions USD)
  - GDP (billions USD)
  - Military expenditure (% of GDP)
  - Arms imports and exports (quantity)

Test Metrics & Clustering

- Stationarity tests (BoxCox, ACF, KPSS), residual analysis, Akaike Information Criterion (AIC)
- Clustering: k-means & hierarchical within-subclass clustering

Models

- Time series: Naive, ARIMA, ARIMAX, & TAR models to model and forecast patent data
- Regression analysis: Poisson, Negative Binomial, Polynomial & Linear to understand the effect of economic indicators on patterns of patent data
- Cross validation: rolling origin & expanding window

Results

Time Series Analysis
ARIMA/ARIMAX

- All ARIMA models required one differencing term to become stationary
- All models underfit the actual data
- ARIMA forecasted a steady trend in patent counts
- Private patent ARIMAX model performed the best according to AIC values
  - Forecasted an increase in patent counts
- F41A17 case study revealed similar fits and forecasts

TAR

- TAR models outperfomed all ARIMA models based on AIC values
- Two-regime TAR models split data into a low and high regime
- TAR models forecasted a decline in patent counts

Regression Analysis
Poisson/Negative Binomial

- Times of war were always significant across all subclasses
- Significance of war and cluster interaction terms varied

Polynomial/Linear

- F41A17 case study: statistical significance of GDP, military expenditure, arms imports, and time

Figure 1: firearm patent counts over time with U.S. war regions
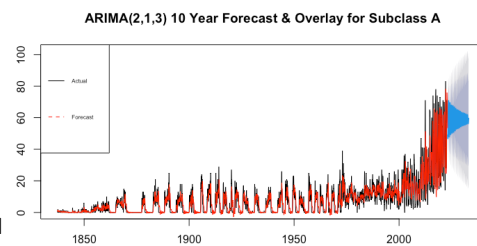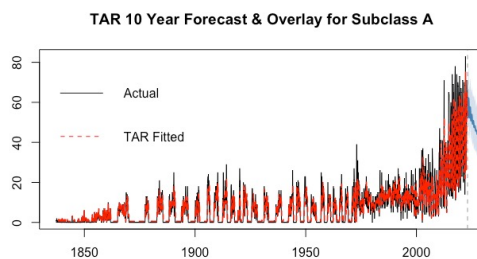

Figure 2: ARIMA forecast & overlay for Subclass A

Figure 3: TAR forecast & overlay for Subclass A
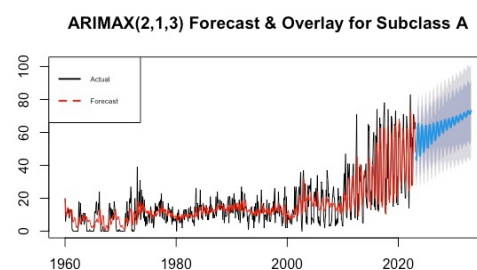
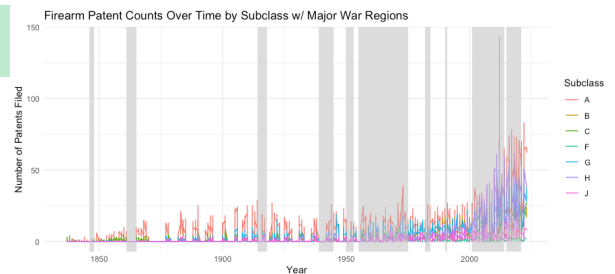*Figure 4*: ARIMAX forecast & overlay for Subclass A Private Patents

Discussion

Time Series

- Using time series models, we were able to effectively model over 200 years of firearm patent data
  - Though these models provided different forecasts, it set a baseline for what to expect as model complexity increases
  - The combination of sporatic publishing and a post 21st century spike likely caused discrepencies in forecasts
- When modeling U.S. Government/Military patents with an ARIMAX that included economic variables, model fit increased dramatically
  - Forecasted an increase in patent counts which makes the most sense intuitively

Regressions

- Count regressions produced statistical significance for times of war, indicating that during these times, patent counts were higher
- Macroeconomic variables were, in general, significant across all subclasses, particularly military expenditure and arms imports/exports