

# Demand Shocks, Procurement Policies, and the Nature of Medical Innovation: Evidence from Wartime Prosthetic Device Patents

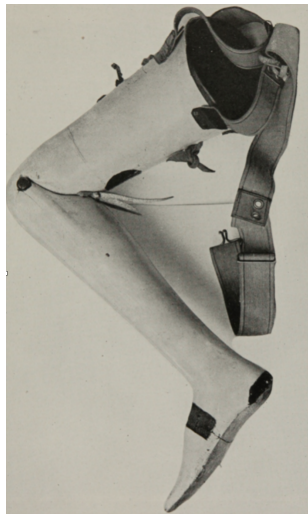
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# Limb Examples



(a) BF Palmer Limb, CW (source: NMHM)



(b) Liberty Limb, WWI (source: OSG)

# Research Questions

1. How do financial incentives affect the volume of medical innovation?
2. How do financial incentives affect the attributes of innovation?
3. Is it possible to see improvements in medical technologies without seeing higher costs?

# Our Contribution

We approach these questions in the context of Civil War and WWI demand shocks/procurement regimes for prosthetic limbs and find:

1. New evidence on demand-driven innovation.
  - ▶ Wartime demand led to increases in prosthetic device patenting.
2. Traits of innovation change meaningfully with demand environments and procurement regimes.
  - ▶ Innovators emphasized lower production costs with cost-conscious procurement regimes.
  - ▶ Theory of how procurement models shape inventors' emphases.
  - ▶ Product quality traits matched third-party payer's desires.
3. New data on economic emphases of patent documents.
  - ▶ Medical and mechanical technologies from 1840-1940.
  - ▶ The variables we've constructed allow us to answer our questions.

# Background on Wartime Shocks to Demand

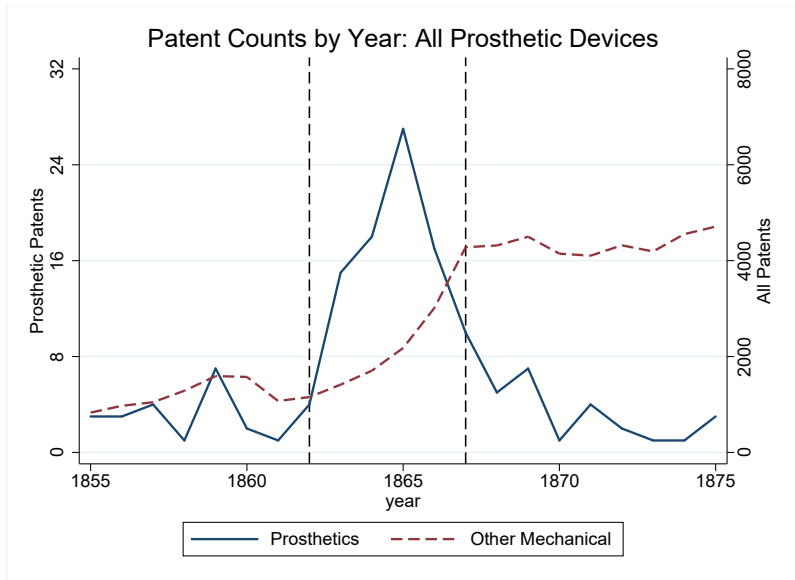
## Civil War:

- ▶ US Delivered 3,798 legs and 2,204 arms as of May 1866 (Hasegawa, 2012).

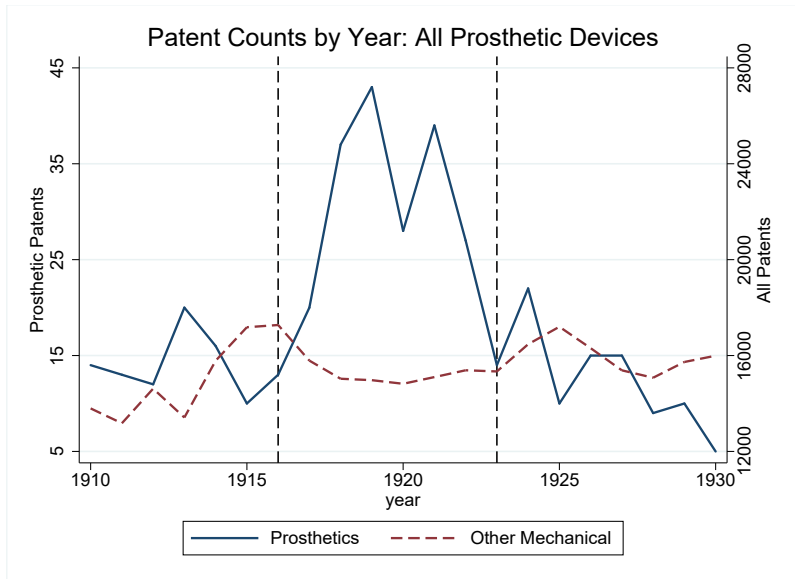
## World War I:

- ▶ Estimated 300,000 amputee survivors world wide.
- ▶ Capacity was low among the European powers but high in the U.S. due to the Civil War legacy.

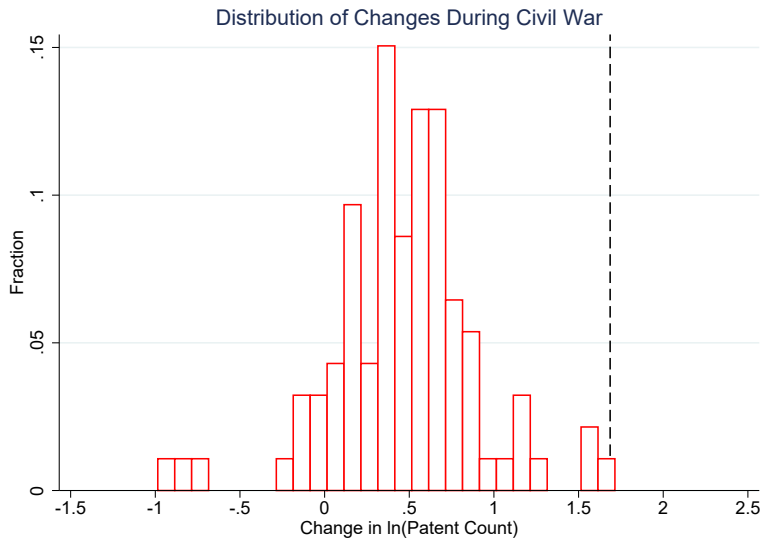
# How Demand Affects Prosthesis Innovation Volume Surrounding the Civil War



# How Demand Affects Prosthesis Innovation Volume Surrounding WWI

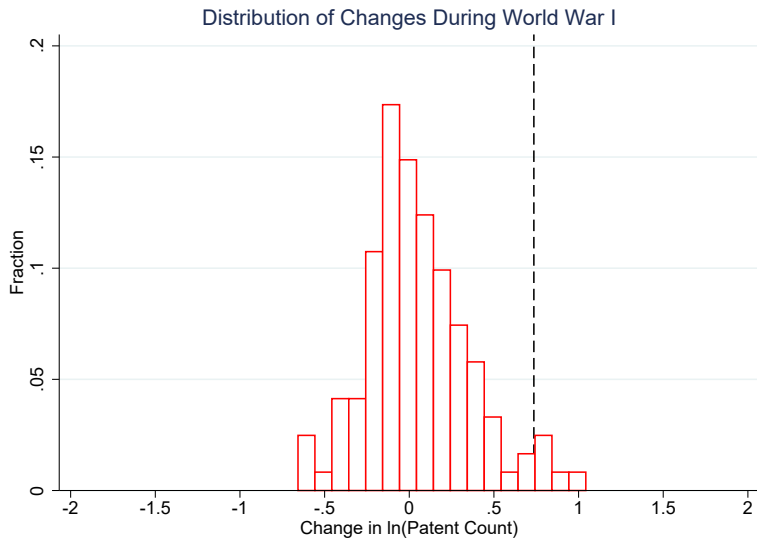


# Changes in $\text{Ln}(\text{Patent Counts})$ : Civil War





# Changes in $\text{Ln}(\text{Patent Counts})$ : World War I



# Why Care about Traits of Innovation?

The value of medical innovation can be improved through many meaningful dimensions.

- ▶ E.g., cancer treatments might be improved through increased life expectancy, reduced side effects, or reduced costs.
- ▶ Innovators must choose to focus effort on certain traits.
- ▶ These choices can depend on financial incentives (Budish et al., 2015).

Distortions to innovation may be particularly relevant in health markets due to regulators and third-party payers.

- ▶ Third-party payers employ reimbursement regimes or approval processes that can affect innovators' financial incentives.

# How Payment Models Shape Innovation Incentives

We provide a conceptual framework (cost vs. quality innovation):

- ▶ Cost-plus rewards quality enhancement
- ▶ Cost-plus eliminates rewards for cost reduction
- ▶ Fixed-price at very high levels can (surprisingly) tilt effort towards quality enhancement
- ▶ Fixed-price at low levels ensures cost-reducing innovation
- ▶ Fixed-price at very low levels will lead firms to opt out of participation

# Coding the Economic Traits of Patents for Analysis

**Goal:** Analyze how demand shocks and procurement regimes shape innovators' emphasis on production-processes and product quality.

▶ **Problem:** The required data did not exist.

Our procedure for generating the data we need:

1. Training data set:

- ▶ Close readings of 1,201 patents (497 prosthetic device patents and 704 other medical and other mechanical patents).
- ▶ **Identify production process traits:** cost , simplicity, adjustability, materials.
- ▶ **Quality traits:** comfort and appearance.

2. Train text analysis algorithm.

3. Use final model to code characteristics of full set of prosthetic device and “control group” patents (700,000 docs).

# Background on Procurement Models

## Civil War:

- ▶ \$75 limb allowance (\$1500 today). Fixed payment per limb.
- ▶ Average production cost per leg: \$115; Market price: \$150.
- ▶ Balance-billing was prohibited.
- ▶ Choice of manufacturer was left to the soldier.

## World War I:

- ▶ Treatment and veteran's benefits were more formalized and centralized during WWI than the Civil War w/ limb provision.
- ▶ Institutional emphasis on "appearance" of amputees and rigorous rehabilitation and reintegration during WWI.

# Overview of Empirical Analysis on Traits

**Broad Question:** Did the characteristics of prosthetic device patents shift during the war-induced patent booms?

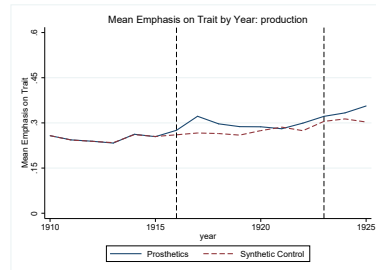
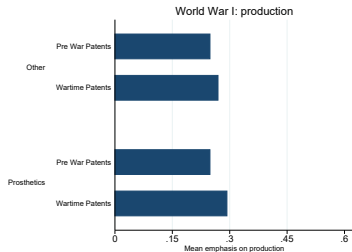
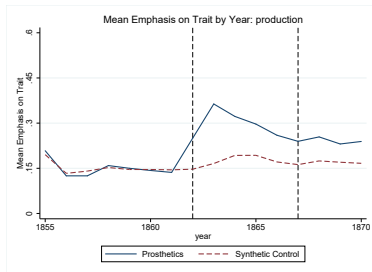
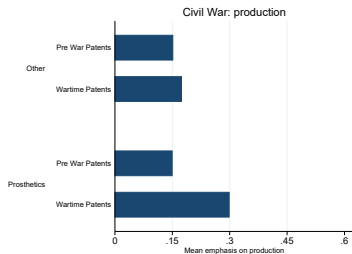
**Specific Example:** Did prosthetic device patents become more cost-focused during the fixed-cost reimbursement procurement regime of Civil War period?

**Outcome Variable:** Share of patents within a given class-year that emphasize the trait of interest.

## Counterfactuals:

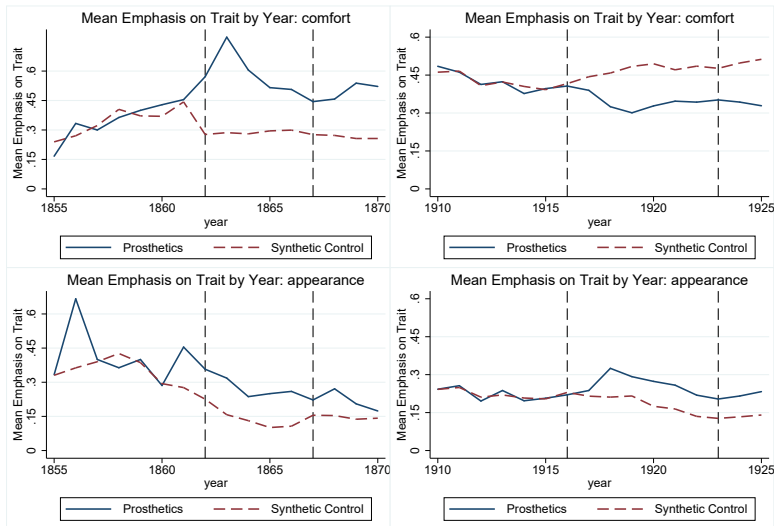
- ▶ **Synthetic control** (this is our preferred approach)
  - ▶ Graphs with 4-year moving averages (need to reduce noise due to years with small numbers of prosthetic device patents).
- ▶ Simply matched control classes.
- ▶ Full sample of other medical and mechanical patents.
- ▶ Manually coded sample of other medical and mechanical patents.

# Production-Process Aggregate across War Episodes



# Divergence in Consumer Facing Traits across War Episodes

## User Traits of Mechanical Patents





# Conclusion

- ▶ More evidence that innovation responds to market size.
  - ▶ War-induced demand led to large increases in prosthetic device patenting.
- ▶ Different environments were associated with differences in the nature of prosthetic device innovation.
  - ▶ Broad set of production process traits emphasized during the Civil War, but not during WWI. Plausibly tied to reimbursement type.
  - ▶ Avg production costs before CW: \$115, after war: \$72.
  - ▶ Medical innovation  $\nrightarrow$  increased costs.
  - ▶ Modest difference in emphasis on appearance.
  - ▶ Dramatic difference in emphasis on patient comfort.
- ▶ New data.
  - ▶ We use text analysis to generate new variables to describe the economic traits of medical innovations.