Bones, Bombs, and Break Points: The Geography of Economic Activity

Donald R. Davis and David E. Weinstein (2002)
presented by David Bohnenberger

Agenda

1. The Aim of the Paper
2. Contribution to the Literature
3. Distribution of Economic Activity: Three Theories
4. Bones: Archeology, History and Economic Geography
   - Principal Features of Historical Economies
   - Variation and Persistence in regional Densities
5. Evaluation of Theories
6. Bombs and Break Points
   - The Nature of the Shocks
   - Instrumental Variable Estimation
   - Robustness Analysis
7. Evaluation of Theories
8. Policy Implication
9. Strengths and Weaknesses of the Paper

The Aim of the Paper

- Examining the distribution of economic activity within a country through three theories:
  1. Increasing returns
  2. Random growth
  3. Locational fundamentals
- **Bones - Archeology, History, and Economic Geography:** Uses regional population data from Japan, spanning from the Stone Age to the modern era
- **Bombs and Break Points:** Analyzes WWII bombing of Japanese cities as a shock to test persistence of city sizes
- **Hybrid model:** locational fundamentals establish basic pattern of relative regional densities and increasing returns determines degree of concentration

Contribution to the Literature

- **Theory Testing in an Evolving Field:**
  - Provides a critical test of theories in the evolving field of economic geography and spatial economics
- **Policy Relevance:**
  - Findings have strong implications for policy, especially regarding spatial concentration and regional development
- **Support for Geographic Importance (Sachs, 2001):**
  - Aligns with other economists stressing the importance of geography in economic outcomes
- **Methodology – Natural Experiment:**
  - Innovative use of a historical shock (WWII bombings) as a natural experiment
  - Utilizes a unique 8,000-year dataset on Japanese regional populations

Distribution of Economic Activity: Three Theories

- **Increasing Returns Theory:** Advantages of large size, knowledge spillovers, and labor market pooling
- **Random Growth Theory:** Cities grow from random processes; explains Zipf's Law
- **Locational Fundamentals Theory:** Geographical characteristics determine size, resilient to temporary shocks

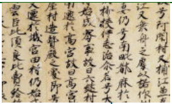
Bones - Archeology, History, and Economic Geography

- **Key Questions:**
  - How much has regional population density varied historically?
  - Have the most densely settled regions remained consistent over time?
- **Data Source:**
  - 8,000 years of data on Japanese regions, providing insights on variation and persistence in population densities
- **Focus on Regions vs. Cities:**
  - Defining a "city" involves population thresholds; uniform population growth may appear nonuniform as locations cross these thresholds
  - Over long time periods, definitions of "city" change (e.g., areas now part of Tokyo were not historically considered urban)
  - In early periods, most people lived outside what we now consider cities, making regional data essential for historical accuracy

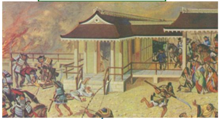
Principal Features of Historical Economies (1)

Jomon period
- hunting and gathering
- no metal tools or agriculture
- evidence of pottery

Feudal regime
- first population census
- writing is well developed
- farming is widespread
- capital is Nara



In the North: Instability and civil war



Two centuries of self-imposed isolation

-6,000 Stone Age -300 300 725 800 1150 1600 1630

Yayoi period
- primitive forms of agriculture, metallurgy, and some coins.
- there is neither writing nor cloth

Capital moved to Kyoto
- protection of peasant property rights encourages widespread cultivation
- extensive usage of metal farm tools, raising productivity

- reunification of Japan - extensive trade and contact with West
- Japan is regional power

Principal Features of Historical Economies (2)

1630

Two centuries of self-imposed isolation

1721

1721, the capital moved to Tokyo and population movement became more restricted

1798

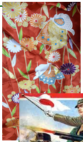
- **80 percent farmers,**
- **6 percent nobility,**
- **remainder: merchants and artisans**

1870's

- civil war
- the end of the Shogun's government
- Jump from autarky to free trade and the subsidized import of Western technology
- ➢ **very start of Japan's industrial revolution**

1920s

- Industrialization and militarization
- major exporter of silk and textiles
- approximately 50 percent of the workforce is still composed of farmers



1998

Japan is a highly industrialized society:

- farmers now comprising 5 percent of population.
- Tokyo amongst the greatest cities with a population of 12 million

TOYOTA

Measures for Variation in Regional Density

- **Share of Population in Five Most Populous Regions:**
  - Jomon Period: High concentration (39 percent) due to limited habitability without agriculture or tools
  - Pre-20th Century: 20-30 percent concentration maintained
  - End of 20th Century: Rise above 40 percent, reflecting increased urban concentration
- **Relative Variance of Log Population Density:**
  - 700–1600: Two-thirds to three-fourths of modern variation, indicating notable density differences
  - 1721–1872: Variation reduced: Japan's closure to trade, diminishing port city populations
  - Reopening and modernization increased regional density variation
- **Zipf Coefficient:**
  - Jomon and Yayoi periods showed high dispersion, aligning closely with Zipf's Law
  - From 725–1600: Modest decline in density variation; sharper decline during Japan's isolation period
  - By 1998: Regional variation rose significantly with industrialization, reaching a Zipf coefficient of 0.96

Zipf Indicator: Variation in Regional Density

- **Zipf's Law for Cities:**
  - Empirical regularity that describes the distribution of city populations.
  - To apply Zipf's Law, rank cities by population, then take the log of both the rank and population
  - Zipf's Law holds if a regression of log(rank) against log(population) yields a slope of -1
- **Evidence from Studies:**
  - Gabaix (1999) found a slope of 1.004 for the U.S.
  - Rosen and Resnick (1980) reported slopes close to -1 for various OECD countries.
- **Interpretation of the Zipf Coefficient:**
  - **Low Coefficient (close to - infinity):** Implies trivial variation in regional density
  - **High Coefficient (close to 0):** Implies population is highly concentrated in a single region
  - A small Zipf coefficient indicates large variation in regional population density

Key Facts on Variation in Regional Density

- **Variation in Regional Population Densities:**
  - Across most periods, regional population densities varied consistently
  - With the exception of Stone Age Japan, Zipf coefficients align with those in modern OECD countries
- **Impact of Japan's Trade Closure:**
  - Two centuries of trade closure led to a substantial reduction in regional population density variation
  - Large port-based regions declined in relative importance, while regions focused on national activity became more prominent
- **Industrial Revolution and Reopening to Trade:**
  - Japan's industrial revolution, paired with its return to international trade, increased regional concentration and variation in population density

Persistence in Regional Population Densities

- **Densely Settled Regions Over Time:**
  - High correlations in regional population densities trace back to the Stone Age
  - Modern regional densities correlate strongly with those from four centuries ago, indicating persistent settlement patterns
  - In 1600, when Japan's population was only 10 percent of its current size, correlations with modern densities were 0.76 (raw) and 0.83 (rank)
- **Speculations on Persistence:**
  - Possible explanation: Japan's mountainous topography may drive persistence, as inviting valleys contrast sharply with uninhabitable mountains

Variation and Persistence in Regional Population Densities

TABLE 1—PRINCIPAL FEATURES OF HISTORICAL ECONOMIES

Year	Population in thousands	Share of five largest regions	Relative var of log population density	Zipf coefficient	Raw correlation with 1998	Rank correlation with 1998	History
−6000 to −300	125	0.39	2.46	−0.809 (0.217)	0.53	0.31	Hunter-gatherer society, not ethnically Japanese, no metal tools or agriculture.
−300 to 300	595	0.23	0.93	−1.028 (0.134)	0.67	0.50	First appearance of primitive agriculture and ethnically Japanese people. Some metallurgical skills, some coins, no writing or cloth.
725	4,511	0.20	0.72	−1.207 (0.133)	0.60	0.71	Creation of feudal regime, population censuses begin, writing well developed, farming is widespread. Capital is Nara.
800	5,506	0.18	0.75	−1.184 (0.152)	0.57	0.68	Capital moves to Kyoto. Property rights for peasant farmers continue to improve, leading to greater cultivation.
900	7,442	0.29	0.68	−1.230 (0.166)	0.48	0.65	Use of metallic farm tools doubles over average for previous 300 years. Improved irrigation and dry-crop technology.
1150	6,836	0.20	0.66	−1.169 (0.141)	0.53	0.73	Multiple civil wars especially in (rice-rich) northern Japan. General political instability and rebellions.
1600	12,266	0.30	0.64	−1.192 (0.068)	0.76	0.83	Reunification achieved after bloody war, extensive contact with West. Japan is a major regional trading and military power.
1721	31,290	0.21	0.43	−1.582 (0.113)	0.85	0.84	Closure of Japan to trade with minor exceptions around Nagasaki. Capital moves to Tokyo. Political stability achieved.
1798	30,531	0.21	0.37	−1.697 (0.120)	0.83	0.81	Population is approximately 80 percent farmers, 6 percent nobility. Population stability attributed to infanticide, birth control, and famines.
1872	33,748	0.18	0.30	−1.877 (0.140)	0.76	0.78	Collapse of shogun's government, civil war, jump to free trade, end of feudal regime, start subsidized import of foreign technology.
1920	53,032	0.25	0.43	−1.476 (0.043)	0.94	0.93	Industrialization and militarization in full swing, but still 50 percent of labor force is farmers. Japan is a major exporter of silk and textiles.
1998	119,486	0.41	1.00	−0.963 (0.025)	1.00	1.00	Japan is a fully industrialized country. Tokyo, with a population of 12 million, is one of the largest cities in the world.

Notes: Population for years prior to 725 is based on Koyama (1978). All time periods have 39 regions with Hokkaido and Okinawa dropped from all years. The relative variance of the log population is the variance of the log of population density in year *t* divided by the variance of the log of population density in 1998. The Zipf coefficient is from a regression of log rank on log population density using 1920 log density as instruments for the years prior to 725 and 1998 data for later years. Standard errors are in parentheses. The correlation columns indicate the raw and rank correlations between regional density in a given year and regional density in 1998.

Three Theories in Light of the Evidence

Stylized Fact	Increasing Returns (IR)	Random Growth (RG)	Locational Fundamentals (LF)
1. Large variation in regional densities at all times	-: The IR model cannot explain high variation through the benefits of size and cumulative advantages completely	+: RG expects variation due to random processes affecting growth.	+: LF attributes variation to inherent locational advantages like terrain and access to resources.
2. Zipf's Law holds approximately for the distribution of regional densities throughout Japanese history	-: IR does not account for the specific distribution pattern seen in Zipf's Law.	+: RG theory supports Zipf's Law, explaining city size through random growth patterns.	+: LF aligns with Zipf's Law, as geographic fundamentals can shape consistent rank order.
3. Rise in variation in regional densities with Industrial Revolution and Reopening	+: IR expects increased variation with industrial growth due to the importance of economies of scale and clustering.	-: RG does not predict specific periods of increased variation.	?: LF does not explicitly account for a specific rise during industrialization.
4. Persistence in regional densities	?: IR could account for persistence through path dependency, though it is not a definitive prediction. IR could also expect radical shifts of regional densities based on technology shift.	?: RG can align with persistence if growth variances remain small, although not guaranteed.	+: LF directly predicts persistence due to stable geographic factors, like natural resources and access to water.

Bombs and Break Points

- Imagine a calamity that destroys a large share of a city's productive capacity and drastically reduces its population
- Key question: Will this temporary shock have permanent effects, or will the city revert to its former status?
- Ideal conditions for an experiment:
  - Large, highly variable, clearly identifiable, and purely temporary shocks.
- Assessment of allied bombing of Japanese cities during World War II as an ideal natural experiment

Bombs and Break Points: Data

- Data covers 303 Japanese cities with populations in excess of 30,000 in 1925.
- Data allows computation of population growth rates for the following periods:
  - Prewar period: 1925–1940
  - Period of the war and its immediate aftermath: 1940–1947
  - Recovery period, with two measures:
    - 1947–1960
    - 1947–1965

Magnitude of Shocks

- **Allied Strategic Bombing of Japan:**
  - Devastation of 66 targeted cities, destroying 2.2 million buildings
  - Loss of two-thirds of productive capacity
  - 300,000 Japanese casualties, with 40 percent of the population rendered homeless
  - Some cities lost up to half of their population (deaths, missing, refugees)
  - Hiroshima, Nagasaki, Tokyo: severe destruction (e.g., nuclear attacks, 80,000 casualties in Tokyo's deadliest air strike)
  - Median urban destruction at 50.9 percent for the 66 targeted cities

Variance of the Shocks

- **High Variability in Impact:**
  - 80 percent of the 300 cities in sample, representing 37 percent of the urban population, were largely untouched by bombings
  - Includes large cities like Kyoto (5th largest at the time), which was not bombed at all
  - Northern cities like Sapporo avoided heavy bombing due to their distance from U.S. bomber ranges

Temporary Nature of the Shocks

- **Concentration in Final War Months:**
  - Intense U.S. bombing began after the capture of key islands (Marianas, Iwo Jima) and new tactics, peaking in the last five months of the war
- **Minimal Long-Term Impact on Geography:**
  - Despite widespread destruction, geographical characteristics were largely unaffected after fires subsided.
  - Exception: lingering radiation in Hiroshima and Nagasaki, raising unique recovery questions
- **Clear Temporariness of Shocks:**
  - Japanese cities remained out of range for most of World War II, making the identified shocks temporary

Modeling the Shocks (1)

$$s_{it} = \Omega_i + \varepsilon_{it}. \tag{1}$$

S_{it} : city i's share of total population at time t
s_{it} : is the natural logarithm
Ω_i : Initial city size
ε_{it} : city-specific shocks

$$\varepsilon_{it+1} = \rho\varepsilon_{it} + \nu_{it+1}. \tag{2}$$

$\rho \in [0, 1]$: persitence parameter
ν_{it} : innovation is an iid error term (contains the bombings)
First-differencing equation (1):

$$s_{it+1} - s_{it} = \varepsilon_{it+1} - \varepsilon_{it} \tag{3}$$

Substitute (2) into (3):

$$s_{it+1} - s_{it} = (\rho - 1)\nu_{it} + [\nu_{it+1} + \rho(1 - \rho)\varepsilon_{it-1}] \tag{4}$$

Modeling the Shocks (2)

- If $\rho = 1$, then all shocks are permanent and city size follows a random walk:

$$s_{it+1} = s_{it} + \nu_{it+1}$$

- If $\rho \in [0, 1)$, then city share will dissipate over time
- By hypothesis: Innovation, ν_{it}, is uncorrelated with the error term, so if we can identify the innovation, we can obtain an unbiased estimate of ρ

Need for an Innovation Indicator

- **Potential candidate for innovation:** Population growth rate from 1940 to 1947
- Growth rate may reflect not only innovation due to postwar rebuilding but also prior growth trends
- This overlap poses a measurement error issue, potentially biasing estimates in either direction

- **Proposed Instrument:** Instrument growth rate from 1940–1947 using:
  - Buildings destroyed per capita
  - Deaths per capita
- Do instruments affect city growth rate from 1947-1960 only through growth rate from 1940-1947?

Impact of Bombing on City Growth Rates

How to understand the relationship between historical shocks and future growth rates?

- Random Walk
  - All shocks are permanent
  - No relationship between past shocks and future growth
- Location-Specific Factors
  - Importance of city-specific factors for population distribution
  - Negative relationship between historical shocks and future growth

Relationship between during and post-War City Growth Rates

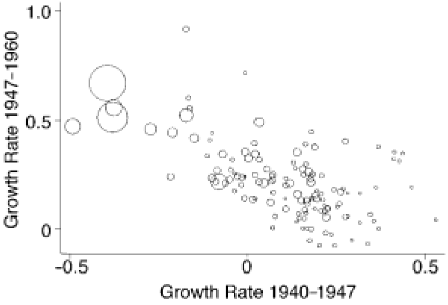


FIGURE 1. EFFECTS OF BOMBING ON CITIES WITH MORE THAN 30,000 INHABITANTS

Note: The figure presents data for cities with positive casualty rates only.

- The figure reveals a clear negative relationship between the two growth rates
- Cities with the largest population declines due to bombing experienced the fastest postwar growth rates
- Conversely, cities with significant population growth during the period had much lower growth rates postwar

Power of the Instruments

TABLE 2—INSTRUMENTAL VARIABLES EQUATION (DEPENDENT VARIABLE = RATE OF GROWTH IN CITY POPULATION BETWEEN 1940 AND 1947)

Independent variable	Coefficient
Constant	0.213
	(0.006)
Deaths per capita	−0.665
	(0.506)
Buildings destroyed per capita	−2.335
	(0.184)
R^2:	0.409
Number of observations:	303

Note: Standard errors are in parentheses.

- Instruments explain 41 per cent of the variance in 1940-1947 city population growth
- Both instruments have expected signs
- Destruction per capita has a stronger impact than deaths per capita

IV Estimation: Set up

- Estimation Equation:

$$s_{it+1} - s_{it} = (\rho - 1)\nu_{it} + [\nu_{it+1} + \rho(1-\rho)\varepsilon_{it-1}]$$

TABLE 3—TWO-STAGE LEAST-SQUARES ESTIMATES OF IMPACT OF BOMBING ON CITIES (INSTRUMENTS: DEATHS PER CAPITA AND BUILDINGS DESTROYED PER CAPITA)

	Dependent variable = growth rate of population between 1947 and 1960		Dependent variable = growth rate of population between 1947 and 1965
Independent variable	(i)	(ii)	(iii)
Growth rate of population between 1940 and 1947	−1.048	−0.759	−1.027
	(0.097)	(0.094)	(0.163)
Government reconstruction expenses	1.024	0.628	0.392
	(0.387)	(0.298)	(0.514)
Growth rate of population between 1925 and 1940		0.444	0.617
		(0.054)	(0.092)
R^2:	0.279	0.566	0.386
Number of observations:	303	303	303

Note: Standard errors are in parentheses.

- Regression of the growth rate of cities between 1947 and 1960 on the growth rate between 1940 and 1947
- The coefficient on growth between 1940 and 1947 corresponds to $(\rho - 1)$
- Deaths and destruction per capita as instruments for 1940 - 1947 growth rates
- Government subsidies are included to control for policies aimed at city rebuilding

IV Estimation: Interpretation

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- Hypotheses for Coefficient on 1940–1947 Growth Rate ($\rho - 1$):
  - Random Walk/Permanent Effect: Coefficient should be zero if shocks are permanent
  - Temporary Shock: Coefficient should be negative if effects are temporary
  - Full Recovery: Coefficient of - 1 implies shock fully dissipated by 1960
- Observed Result: Coefficient - 1.048, indicating recovery; typical city regained pre-war size within 15 years
- No lasting impact from U.S. bombing on Japanese cities; rejects random walk hypothesis for city growth

Potential Bias and Adjusted Analysis

- **Challenge to Results (1):**
  - Possible U.S. targeting bias: Cities bombed based on underlying growth rates may skew results
  - Although not an explicit strategy, if rapidly growing cities were more heavily bombed, results could be biased downwards
- **Adjusted Analysis:**
  - Included 1925–1940 growth rate as an additional independent variable
  - Improved fit but did not qualitatively change results; coefficient on 1940–1947 growth reduced to - 0.76
  - Interpretation: Bombed cities recovered over three-fourths of lost growth by 1960

2 Stage Least Squares Estimation

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Long-Term Recovery and Extended Analysis

- **Challenge to Results (2):**
  - Key question: Did bombed cities return to their pre-war growth trajectories?
  - Location-specific model suggests coefficient on wartime growth should approach unity over time
- **Extended Analysis to 1965:**
  - Regression extended to 1965; coefficient on wartime growth reaches -1.027.
  - Conclusion: By 1965, cities fully reversed war damage after accounting for prewar growth trends

2 Stage Least Squares Estimation

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Challenge of Population Movements? Hiroshima and Nagasaki

- **Challenge to Results (3):**
  - Population changes mostly due to refugees, not deaths (only 1 percent death rate on average in 144 cities)
  - Forced relocation likely temporary; residents may return due to social ties and familiarity
- **Exception Cases: Hiroshima and Nagasaki:**
  - High death tolls make refugee return unlikely: 8.5 percent of Nagasaki's and 20.8 percent of Hiroshima's population killed.
  - Radiation fears and discrimination reduced attachment and external attraction to these cities
  - Not Japan's largest or most famous cities (8th and 12th largest in 1940); nearby cities could have absorbed displaced populations
- **Population Trends:**
  - Both cities show return to prewar growth trends
  - Hiroshima's recovery slower than others, consistent with higher destruction level

Population Growth Trends: Hiroshima and Nagasaki

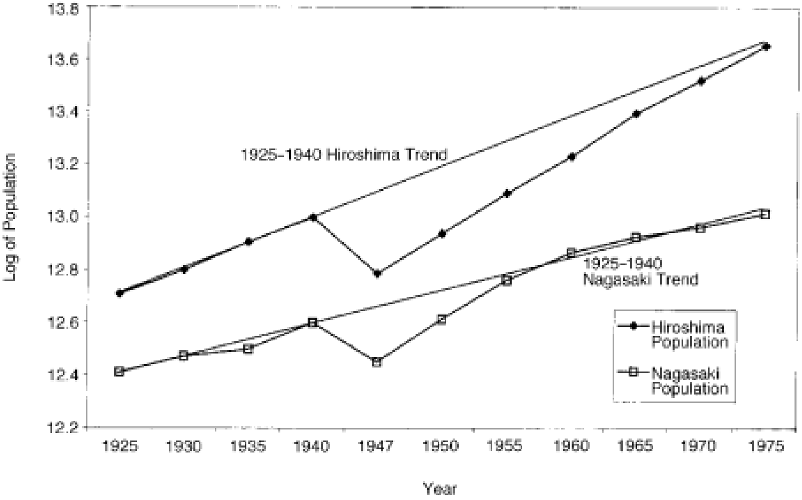

FIGURE 2. POPULATION GROWTH

Three Theories in Light of the Evidence

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4. Persistence in regional densities	?: IR could account for persistence through path dependency, though it is not a definitive prediction. IR could also expect radical shifts of regional densities based on technology shift.	?: RG can align with persistence if growth variances remain small, although not guaranteed.	+: LF directly predicts persistence due to stable geographic factors, like natural resources and access to water.
5. Even strong temporary shocks have no permanent impact on the relative size of cities	?: IR suggests a potential for permanent shifts due to catastrophic shocks but doesn't fully predict reversion.	-: RG assumes shocks have lasting effects, contradicting mean reversion.	+: LF supports mean reversion, as temporary shocks should not permanently change geographic advantages.

Policy Implication: Importance of Locational Factors

- **Relevance to Policy Discussions:**
  - Renewed interest in economic geography stems from ideas like cumulative causation, path dependence, and critical break points
  - But do temporary policy interventions impact the long-run spatial structure of economic activity, influencing welfare really?
- **Stability of Spatial Structure:**
  - Large-scale destruction (up to 50 percent of structures and 20 percent of population) has little effect on a city's long-term relative size
  - Raises question: How likely are temporary subsidies to meaningfully change an economy's spatial structure?
- **Geography as Destiny?:**
  - Key questions: Do tropical climates, lack of coasts, or absence of navigable rivers hinder development long-term?
  - Results support the view that deep, likely geographical characteristics significantly shape growth potential within a technological regime

Strengths and Weaknesses of the Paper

Strengths

- Comprehensive and convincing assessment of the three most famous theories
- Creative use of historical data, integrating contextual knowledge (e.g., different types of bombs)
- Cool use of IV and intuitive robustness checks

Weaknesses

- Lacks an "AHA" effect
- Why include Zipf coefficient?
- First and second parts feel slightly disconnected
- First part already provides rich historical context—consider extending this into a more detailed narrative on locational fundamentals

Thank you for your Attention