Where an Industry Keeps Its Memory

Persistence of Regional Sector Employment after the 2008 and 2020 Shocks, with a Registered Forecast for 2026

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Abstract

When a shock removes part of an industry from a place, does the industry grow back to where it was? Three answers compete. Locational fundamentals predict full regrowth. Agglomeration predicts that the loss persists because the stock of firms, workers and suppliers is itself the advantage. Institutional commitments predict that whatever is written down at the time of the shock governs what follows. This paper borrows a framing from deer antler biology. An injury to one season's antler can reappear at the same site on later antlers, grown after the injured one was shed. The question here is which of three memory stores carries the regrowth of regional industry. Using U.S. Bureau of Labor Statistics QCEW private employment for metropolitan areas by NAICS sector, 2001 to 2025, and the Davis and Weinstein (2002) specification, the pooled slope of post-shock growth on shock-period growth is −0.26 (s.e. 0.03; 2,947 cells) nine years after the 2008 shock and −0.09 (s.e. 0.03; 2,896 cells) five years after the 2020 shock. The 2020 sign reverses when endpoints are two-year averages, so that estimate is provisional, and the standard errors assume independent cells. Placebo slopes are positive (+0.13 and +0.15), so the 2008 result is not generic mean reversion. Full regrowth is rejected for the 2008 episode, where roughly three quarters of the relative loss from 2007 to 2010 persisted to 2019. Solving a geometric pull model for each episode gives implied rates of 3.3 percent a year for 2008 and 1.8 percent for 2020. Each rate is fitted to a single slope and is a summary, not a test. The paper closes with a forecast of 2,896 cell-level probabilities for the 2026 annual averages, written on 16 September 2026 using annual data through 2025, hashed (SHA-256) and published with scoring rules fixed in advance. The author had also seen first-quarter 2026 county data, which were not used in the model.

Keywords: industrial organization; economic geography; hysteresis; path dependence; agglomeration; registered forecast.
JEL: L11, R11, R12, J21, E32.

1 Introduction

In 1965 two researchers reported that a wound to a growing deer antler can reappear the following season, at the same place, on an antler grown after the injured one was shed [1]. The tissue that carried the injury is gone. Something else holds the record. The phenomenon is called trophic memory, and its mechanism is still not settled.

Industries face a version of the same question. A recession, a pandemic or a tariff removes firms and jobs from a metropolitan area. The firms that closed do not come back. Some years later

the sector in that place has regrown. Whether it regrows to its old relative size, or keeps the scar, depends on where the economy stores its memory of the earlier configuration.

This paper sets out three candidate stores, states what each predicts for measured data, and tests them on the two largest U.S. employment shocks of the past twenty-five years. It then does something empirical papers in this literature rarely do. It publishes a dated, hashed forecast for a year whose annual data did not exist when the forecast was made. One quarter of 2026 had been published and was inspected, as Section 3 states. Someone other than the author can therefore score the model.

The contribution is threefold. First, a compact framing that maps three established theories of spatial persistence onto three memory stores with distinct, testable signatures. Second, a replication of the Davis and Weinstein test at the level of metropolitan area by sector for two recent shocks, with placebo checks. Third, a registered forecast with explicit resolution and scoring rules.

2 Three memory stores

Let $E_{a,s,t}$ be private employment in metropolitan area a, sector s, year t, and $E_{s,t}$ national employment in the same sector. Relative employment is

$$y_{a,s,t} = \log E_{a,s,t} - \log E_{s,t}. \tag{1}$$

A shock between a peak year p and a trough year τ moves y by $\Delta^{\text{shock}} = y_\tau - y_p$. Recovery to year T is $\Delta^{\text{post}} = y_T - y_\tau$.

Fundamentals. Each cell has a fixed natural level $y^*_{a,s}$ set by geography, endowments and access. Shocks are transitory. Over a long horizon the cell returns to y^*, so $\Delta^{\text{post}} = -\Delta^{\text{shock}}$ and the regression slope is -1. This is the locational fundamentals view tested by Davis and Weinstein [2].

Trace. The advantage of a place in a sector is the accumulated stock of firms, specialised labour and suppliers [3, 4]. A shock depletes the stock and the depleted stock becomes the new starting point. The stock is pulled toward fundamentals only slowly. With a geometric pull at rate λ a year, the expected slope t years after the trough is

$$\beta(t) = -\left[1 - (1-\lambda)^t\right]. \tag{2}$$

At $\lambda = 0$ the loss is permanent (slope 0). As $\lambda \to 1$ the trace store converges to the fundamentals store.

Ledger. Institutional commitments made at the time of the shock (incentive packages, closures written into contracts, zoning, consent decrees, licences) are read exactly for a fixed number of cycles and then expire. The ledger store predicts a slope near zero while the commitments bind and a discrete change when they lapse. It is the least studied of the three and the hardest to measure with employment data alone.

The antler framing is used here as a device for keeping the three stores distinct, not as a claim about biology. In the antler, the injured tissue is shed, so the memory cannot be stored in the antler itself. In the economy, the closed firms exit, so the memory cannot be stored in those firms. In both cases the question is which surviving structure carries the record.

3 Data

The source is the U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages (QCEW) [5], annual averages, private ownership, metropolitan statistical areas by NAICS sector,

2001 to 2025, with national sector totals alongside. A cell is one area and one sector.

Two construction issues matter. First, metropolitan delineations changed within both windows. An area is screened out of an episode when its published private total moved more than 5 percent against the national total across a delineation change, which removes 93 areas from the 2008 cast and 78 from the 2020 cast. Cells also need at least 1,000 jobs in the peak year and data in every year of the window. Second, from the third quarter of 2025 BLS publishes metropolitan QCEW data only as all-industry totals. Metropolitan detail by industry was discontinued, starting with data released on 10 March 2026 [6]. Values for 2025 are therefore spliced from county rows under the July 2023 CBSA delineation. The 2024 metropolitan level is multiplied by the ratio of 2025 to 2024 employment, summed over counties disclosed in both years. A cell is kept only when county coverage lies between 70 and 130 percent of the metropolitan figure. A 2026 first-quarter reading spliced the same way was inspected before the forecast was written but was not used in any estimate.

4 Specification

Following Davis and Weinstein [2], post-shock growth is regressed on shock-period growth across cells,

$$\Delta_{a,s}^{\text{post}} = \alpha + \beta\, \Delta_{a,s}^{\text{shock}} + \varepsilon_{a,s}. \tag{3}$$

A slope of -1 means the shock was fully reversed. A slope of 0 means it was fully kept. Because y is measured relative to the national sector, national cycles and sector-wide trends are removed by construction.

Two episodes are examined. For the 2008 cast the peak is 2007, the trough 2010 and the end year 2019, nine years after the trough. For the 2020 cast the peak is 2019, the trough 2020 and the end year 2025, five years after the trough.

A negative slope can arise from mean reversion in noisy cell-level data even without any shock. The placebo replaces the shock with growth over a pre-shock window of the same length, 2004 to 2007 for the 2008 cast and 2016 to 2019 for the 2020 cast, and regresses the same post-shock regrowth on it. If the negative shock slopes were a generic product of measurement noise, the placebo slopes would also be negative.

5 Results

	2008 cast	2020 cast
Peak, trough, end year	2007, 2010, 2019	2019, 2020, 2025
Years after trough	9	5
Cells	2,947	2,896
Areas screened for delineation change	93	78
Pooled slope β (s.e.)	-0.261 (0.033)	-0.087 (0.034)
Placebo slope (s.e.)	$+0.13$ (0.03)	$+0.15$ (0.02)
Slope, two-year averaged endpoints	-0.19	$+0.10$
Median within-area sector rank correlation, peak to end	0.955	0.976
Implied trace pull λ (per year)	0.033	0.018
Implied half-life of the trace (years)	about 21	about 38

Table 1. Main estimates. Slopes from the Davis and Weinstein specification on relative log employment. The implied pull solves $\beta(t) = -[1 - (1 - \lambda)^t]$ for the unrounded observed slope. Standard errors are conventional and assume independent cells.

Full regrowth is rejected for 2008. The 2008 slope is far from −1. Nine years after the 2010 trough, about one quarter of the relative loss incurred from 2007 to 2010 had been made good, and three quarters remained. The 2020 slope is also far from −1, but it changes sign when endpoints are averaged over two years, so the 2020 estimate is not yet stable.

The result is not mean reversion. Placebo slopes are positive in both episodes, +0.13 and +0.15. In years without a shock, relative growth persists rather than reverting, so the negative shock-window slopes are not a product of measurement noise alone.

The ordering of sectors within a place barely moves. The median within-area rank correlation of sectors from peak to end is 0.955 after 2008 and 0.976 after 2020. Shocks change levels, not the composition ranking of what an area is good at.

A slow pull summarises both episodes. A geometric pull of 3.3 percent a year reproduces the 2008 slope at nine years. A pull of 1.8 percent reproduces the 2020 slope at five years. Each rate is solved from one slope, so it summarises the episode and does not test the model. Figure 1 plots both curves with the observed points. The 2020 estimate is early and its averaged-endpoint version is positive (+0.10), so the 2020 pull should be read as provisional.

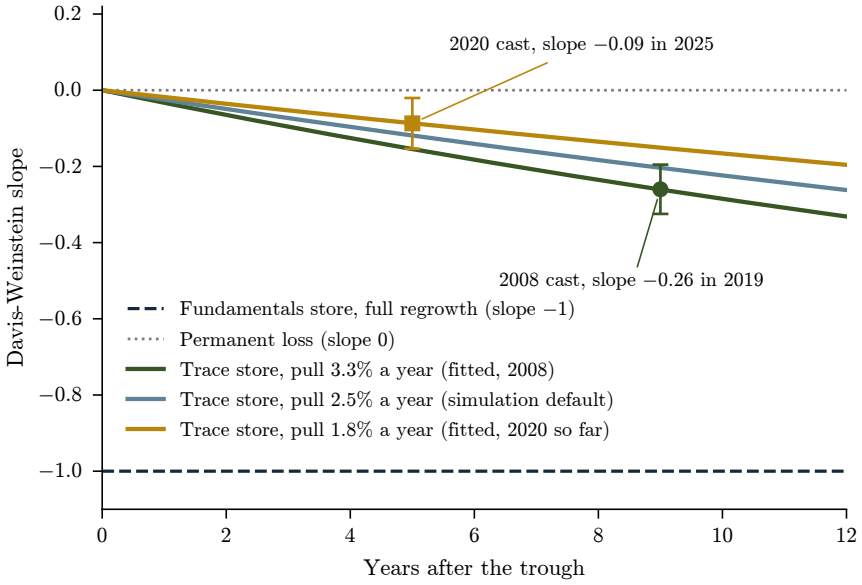


Figure 1. Predicted slope paths for the fundamentals store (dashed) and the trace store at three pull rates, with the observed pooled slopes and 95 percent intervals. The fundamentals store is rejected in both episodes.

The 2020 cast splits by sector. Arts and entertainment, accommodation and food services, and administrative services regrew, with sector-level slopes between −0.4 and −0.7. Finance, health care, management of companies and wholesale trade show positive slopes, meaning that cells which fell during 2020 kept falling. This is consistent with a temporary closure shock in consumer-facing services and a reallocation shock, possibly linked to remote work, in office-based sectors. The data here cannot separate those two mechanisms.

Ectopic branches. By analogy with the antler, a cell is classed as an ectopic branch if its relative log employment stood at least 0.2 away from its pre-shock level, roughly 20 percent, in each of the last three years of the window. These cells, 60 after 2008 and 23 after 2020, are cases where the shock left a new shape rather than a dent. They are listed with their paths in the online companion.

6 Relation to the literature

Davis and Weinstein [2] found that Japanese city sizes returned to their prewar trend within about fifteen years of the Allied bombing, and read the result as support for locational fundamentals. Brakman et al. [7] found that the bombing's effect on city growth was temporary in West Germany, as in Japan, but not in East Germany. Bleakley and Lin [8] showed that portage sites retain population long after portage became obsolete, a clear case of the trace store outliving its fundamental. Blanchard and Katz [9] found that state-level employment shocks are absorbed largely through migration, with relative employment permanently lower. Yagan [10] found that a one percentage point larger 2007 to 2009 local unemployment shock reduced 2015 working-age employment rates by more than 0.3 percentage points. Amior and Manning [11] documented persistent local joblessness across U.S. areas.

On the industrial organization side, the online companion includes a synthetic season model that combines Cournot competition with free entry against a sunk cost [12] and an entry, learning and shakeout cycle [13]. Its parameters, described on the companion's method page, are chosen for legibility and are not estimates. The empirical part of this paper is narrower than either. It measures persistence and does not identify which structural mechanism produces it.

The present estimates sit between the Japanese result and the Blanchard and Katz result. They are closer to persistence than to full recovery, yet the regrowth is measurable. One possible reason for the difference from Davis and Weinstein [2] is that bombing destroyed capital in place while leaving firms, skills and claims to land, whereas a recession removes firms. This paper does not test that explanation.

7 Registered forecast for 2026

A forecast that can only be checked by its author proves little. On 16 September 2026, using annual data through 2025, a forecast was written for every cell in the 2020 cast. The first-quarter 2026 county reading had been seen but was not an input. The published file records it beside each cell for transparency.

Target. For each cell, the probability that relative employment in 2026 is at or above its 2019 level, $P(y_{2026} \geq y_{2019})$.

Model. A logistic model on the remaining gap to 2019, the most recent annual change, cell size and sector group, trained on transitions from the 2008 episode (2011 to 2019) and the 2020 episode (2022 to 2024). On held-out 2024 to 2025 transitions the Brier score [14] was 0.0653, against 0.2466 for the base rate and 0.0774 for naive persistence.

Aggregates with 80 percent intervals. Pooled 2026 slope -0.08 (-0.14 to -0.03). Share of cells at or above their 2019 level 43.1 percent (41.7 to 44.5). The file also contains forty named calls and 23 calls on ectopic branches.

Registration. The predictions file is 518,279 bytes with SHA-256

`fae032413a55b76346ad985c93982384777f1d7348b6686b693646e5f3d739da`

and is served at `https://www.abhaychakra.com/p/pedicle/data/predictions.json`. The hash and the predictions file were published on the author's site on 16 September 2026. Until this paper is deposited with a persistent identifier, that date rests on the author's word alone. The deposit date is the first independent timestamp, and readers who need certainty should treat it as the registration date.

Resolution and scoring. The forecast resolves when BLS publishes 2026 annual averages, expected around June 2027. Because metropolitan rows by industry are no longer published, the county

splice described in Section 3 is applied unchanged. Cells are scored by Brier score against the same two benchmarks. Aggregates are scored by whether the realised value falls inside the stated interval. Results will be reported whatever they are.

8 Limits

Relative employment is a narrow measure that ignores wages, output and the identity of firms. The specification measures persistence, not its cause; agglomeration, durable housing [15] and selective migration all predict negative slopes short of -1. The ledger store has not been tested here, because employment data carry no record of the commitments made at the time of a shock. The 2025 splice introduces measurement error that is largest in small areas. Five years is short for the 2020 episode. Cells in the same area share local shocks, so standard errors that allow for correlation within areas would be wider than the conventional ones reported, and they have not been computed. The estimation script has not yet been published, so the slopes cannot yet be recomputed by readers from this paper alone.

9 Data and code availability

All inputs are public BLS QCEW files. The interactive companion, method page, episode summaries (slope paths, placebo and two-year estimates, sector table and ectopic cells), and the registered predictions with their hash are at `https://www.abhaychakra.com/p/pedicle/`.

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References

[1] Bubenik, A. B., and Pavlansky, R. (1965). Trophic responses to trauma in growing antlers. *Journal of Experimental Zoology*, 159(3), 289-302. doi:10.1002/jez.1401590302.

[2] Davis, D. R., and Weinstein, D. E. (2002). Bones, bombs, and break points: The geography of economic activity. *American Economic Review*, 92(5), 1269-1289. doi:10.1257/000282802762024502.

[3] Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy*, 99(3), 483-499.

[4] Arthur, W. B. (1989). Competing technologies, increasing returns, and lock-in by historical events. *Economic Journal*, 99(394), 116-131.

[5] U.S. Bureau of Labor Statistics (2026). Quarterly Census of Employment and Wages, annual averages 2001 to 2025. Accessed 16 September 2026. `https://www.bls.gov/cew/`

[6] U.S. Bureau of Labor Statistics (2025). Change in the presentation of Metropolitan Statistical Area data in QCEW. `https://www.bls.gov/cew/notices/2025/change-in-the-presentation-of-metropolitan-statistical-area-data-in-qcew.htm`

[7] Brakman, S., Garretsen, H., and Schramm, M. (2004). The strategic bombing of German cities during World War II and its impact on city growth. *Journal of Economic Geography*, 4(2), 201-218.

[8] Bleakley, H., and Lin, J. (2012). Portage and path dependence. *Quarterly Journal of Economics*, 127(2), 587-644.

[9] Blanchard, O. J., and Katz, L. F. (1992). Regional evolutions. *Brookings Papers on Economic Activity*, 1992(1), 1-75.

[10] Yagan, D. (2019). Employment hysteresis from the Great Recession. *Journal of Political Economy*, 127(5), 2505-2558. doi:10.1086/701809.

[11] Amior, M., and Manning, A. (2018). The persistence of local joblessness. *American Economic Review*, 108(7), 1942-1970.

[12] Sutton, J. (1991). *Sunk Costs and Market Structure*. Cambridge, MA: MIT Press.

[13] Klepper, S. (1996). Entry, exit, growth, and innovation over the product life cycle. *American Economic Review*, 86(3), 562-583.

[14] Brier, G. W. (1950). Verification of forecasts expressed in terms of probability. *Monthly Weather Review*, 78(1), 1-3.

[15] Glaeser, E. L., and Gyourko, J. (2005). Urban decline and durable housing. *Journal of Political Economy*, 113(2), 345-375.