Do court-ordered breakups spur innovation?

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Abstract

Breaking up a monopoly may have stimulated innovation in oil refining over decades. In the shorter run, the immediate demand for oil may have spurred more innovation. [JEL K21, L42, L65]

I. Introduction

Are larger firms more likely to innovate? Schumpeter (1950) conjectured that big firms have enough money to finance new products that transform the market. In 1953, however, small firms produced patents at an average cost that was half that for large firms. Small firms were also more likely to market the inventions that they patented.[2] In the making of chemicals, petroleum and steel, very large firms produced fewer significant inventions than did slightly smaller firms, concluded a multi-case statistical study.[3] This finding suggests that market power may not stir much innovation, since major inventions appear critical to innovation. In oil refining, for example, important inventions led both ordinary inventions and investment in two growth periods, one stimulated by the demand for kerosene and the other by the demand for gasoline.[4] These findings are consistent with the idea that competition spurs innovation.

This paper asks whether an industry might have innovated more or less after a court-ordered breakup of large firms. It tests whether the oil-refining industry in the United States issued more patents after the Supreme Court, in May 1911, ordered the rupture into 34 firms of Standard Oil of New Jersey, which had refined three-fourths of the crude oil and more than four-fifths of the kerosene in that era.[5] While the offspring of Standard remained important in the industry – refining 44 percent of the crude in 1919 – each was confined to a district and thus was more vulnerable to local competition than before. No longer in existence was Standard's old trust, the Central Association of Refiners, through which it had controlled the crude production, refining, and transport of oil.

Section II describes data. Patents represent innovations, and a dummy variable tracks whether the oil refining industry received more patents after the Standard Oil breakup than before. Section III presents results. The stimulus of the breakup to patenting is weaker in the medium run than in the long; demand factors, such as spending on gasoline and motor oil, seem to matter more. Section IV concludes.

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2 Schmookler, 1972.

3 Mansfield, 1964.

4 Schmookler, 1962.

5 Ise, 1926, p. 225. The Supreme Court opinion concluded that Standard Oil had controlled 90 percent of the oil business until 1882, when it began forming trusts.

II. Data

In oil refining, the number of patents may respond to supply factors, such as scientific discoveries (proxied here by a time variable, *Year*). Or the number of patents may respond to demand factors. The oil refinery may observe the demand for its products directly, from the prices and units sold of its products. One may simplify the model by substituting the wellhead price and barrels sold of crude oil for prices and quantities of refined products. As an alternative, the oil refinery could observe the demand for two of its most popular refined products by observing consumer spending on gasoline and motor oil. Finally, the refinery could infer demand for its products from two broader variables: The number of consumers; and spending on military machines and transport. These variables are described below.

Oil is the number of 42-gallon barrels of crude oil extracted in the United States, in units of thousands. *Price* is the inferred nominal price of a barrel at the well; it is computed by dividing the well value of the oil by the number of barrels.[6] Both series are from Ise (1926, Appendix A).

Schmookler (1972) has counted the number of patents granted in oil refining from 1852 through 1957. His time series assign the patents by date of grant for 1852-1873 and for 1951-1957; and by date of application instead for 1874-1950.

Other annual time series used here are from the *Historical statistics of the United States* (1975). *Income per capita* is in 1958 dollars, adjusted by the Consumer Price Index. *Gas* gauges personal consumer spending on gasoline and motor oil, in 1967 dollars, adjusted by the CPI. *Military capital* measures spending on physical capital in defense, in 1967 dollars, adjusted by the CPI.[7] The paper estimates it by subtracting military wages and salaries from total military spending by the federal government. *Population* is in units of thousands.[8]

III. Tests

A. Medium-run models

The following estimates are for a model in which the refiner may infer demand for his products from the demand for crude. It is assumed that, as the owner of land, the producer of crude oil will capture a share of the rent for refined oil; and that the share will remain constant over time. The time series extend from 1876 through 1922, or until 11 years after the Supreme Court ordered the breakup of a monopoly in *Standard Oil Company of New Jersey vs. United States* (221 *US* 1, 1910 term). This seems to allow enough time to observe how the court decision immediately affected the structure of the industry.

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[6] Estimates of real prices may prove spurious for this time series, since it predates technological innovations after 1923.

[7] The CPI is used since taxation for military spending connotes a sacrifice of consumer goods.

[8] For each data series, the standard deviation seems large enough relative to the mean to use the series as a variable.

In the first model, *Patents* depends on the crude price and amount of oil supplied two years before application for the patents. This reflects a presumption that the refinery typically would have started research and development two years before applying for the patent. The two-year lags of the price and amount produced of crude are *LagPrice* and *LagOil*. A dummy variable*, Court,* indexes time before and after the Supreme Court decision of 1911; it takes the value of 0 up to 1911 and the value of 1 from 1911 through 1922.

Variable	**Observations**	**Mean**	**Median**	**Standard deviation**
Oil	47	135862	60960	139394
Price	47	1.0357	0.8504	0.5547
Patents	47	48.43	0.8504	63.69
LagOil	47	141401	63621	139916
LagPrice	47	0.9729	0.8057	0.4761

Figure 1: Descriptive statistics for medium-run model

This model does not suggest that the breakup of Standard rapidly stimulated innovation in oil refining. The *Court* coefficient is negative, implying that the industry applied for fewer patents after the breakup; the *t*-statistic, however, is only -.17, throwing the result into doubt.[9] Neither do supply shocks, such as basic discoveries, seem to have spurred innovation. The *Year* coefficient is negative, with a *t*-statistic of -3.75. This is consistent with the idea that the number of basic discoveries that are relevant is finite in the short run.

Demand seems to have spurred innovation more than either market structure or supply. The coefficient on the two-year lag of oil output is positive, with a *t*-statistic of 6.22, despite the likelihood of multicollinearity (the Variance Inflation Factor for *LagOil* is 11.6). The impact of demand on innovation may be mildly elastic: Evaluated at the means, the point elasticity of the number of patents relative to the number of barrels of oil extracted is 1.32.

High crude prices may also spur innovation – either to lower input cost, by refining a greater share of the crude into usable product; or to respond to this price signal of greater demand for oil products. The spur of price to innovation may be relatively gentle, however. The coefficient on the two-year lag of wellhead prices is positive, but it implies a point elasticity of patents with respect to well prices of only .266. The coefficient on the *t*-statistic is only 1.42.

For example, the rise in demand for gasoline in the World War I era might have spurred demand for crude oil and consequently for innovations to refine gasoline. Until 1913, oil refining provided only 12 percent of the gasoline used. In the following decade, however, refineries innovated a way to heat hydrocarbons that broke them down into smaller molecules and, as by-product, eventually yielded more than twice as much gasoline. Such innovations in thermal cracking enabled refineries to provide 45 percent

[9] The inconclusive Durbin-Watson test, however, raises the possibility that serial correlation has inflated the variance of the coefficient estimate.

of the gasoline used.[10] In 1928, a French engineer, Eugene Houdry, used activated clay to catalyze cracking to produce higher-octane gasoline. Apparently he was motivated by his interest in auto racing and by the growing market for gasoline (Desmond, 1987; Jewkes; Travers, 1994).

Patents = 4069 - 2.6 Court - 2.16 Year +0.000469 LagOil + 13.2 LagPrice		
47 *Observations*	*Adjusted* R^2 *= .83*	*Durbin-Watson = 1.49*
Variables	**Coefficients**	**Standard deviation**
Constant	4069	1090
Court	-2.62	15.02
Year	-2.1645	0.5769
LagOil	0.00046946	0.00007548
LagPrice	13.223	9.344

Figure 2: Lag model of medium run

The results suggest this possibility: Because research and development are long-run activities, the refinery may want to budget them according to factors that it can easily predict, such as oil output, which rose steadily at about 9.1 percent per year in this era. In the figure below, an exponential curve *SimOil* tracks the actual path of oil output, *Oil*, with an average relative error of about 4.8 percent.

[10] Henglein, 1969, pp. 574-576; Travers, 1994, pp. 454-5.

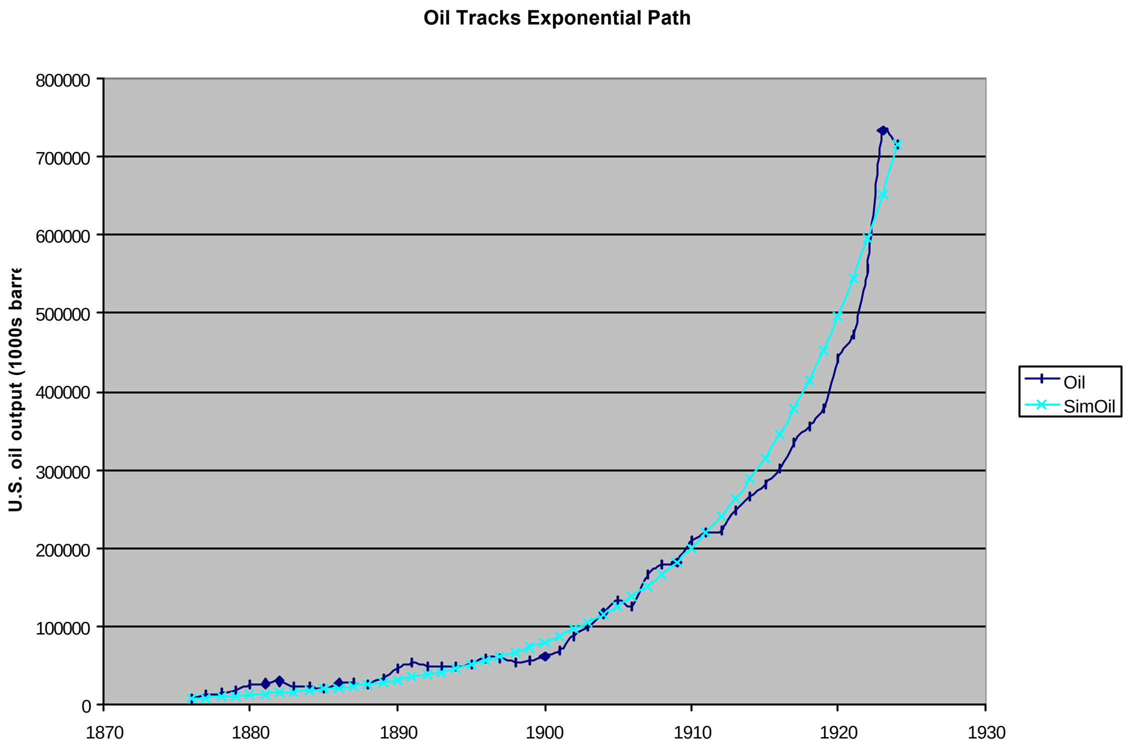

Figure 3: Oil output

If refineries look forward, then they may base their R&D spending upon realistic expectations of the market. They may thus project prices and output for no more than two years ahead; longer projections may be less reliable. This reasoning suggests that the number of patent applications may relate to current prices and output of crude oil. The model below addresses that possibility.

It is slightly more powerful than the lag model: Adjusted R^2 is .902, as opposed to .83 for the lag model. Both models produce similar results: Oil output, not the court-ordered breakup, relates positively to patent applications.[11]

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[11] The Durbin-Watson test suggests serial correlation.

Patents = 3748 - 2.00 Year +0.000580 Oil + 16.5 Price - 6.3 Court		
47 *observations*	*Adjusted* R^2 *= .902*	*Durbin-Watson = 1.02*
Variables	**Coefficients**	**Standard deviation**
Constant	3748	1049
Year	-1.9980	0.5543
Oil	0.00057994	0.00007175
Price	16.481	6.898
Court	-6.28	13.46

Figure 4: Concurrent model of medium run

B. Longer-run models

Supply factors may have accounted for more of the technological progress in the oil refining industry than did demand factors from 1889 through 1957. One might expect that basic discoveries would have more impact in the longer run. The annual number of patents granted relates positively to a time trend and to a dummy variable for the breakup (Figure 8). The number of patents granted to the petroleum refining industry rose from 33 in 1911 to 74 in 1913. After 1916, and until the end of the data series, in 1957, the annual number of patents granted never again dropped below 116. In addition to the Standard Oil breakup, possible causes of the rise in patents include a rise in automobile-related sales and in military spending on capital (Figure 9).

Variable	**Observations**	**Mean**	**Median**	**Standard deviation**
Income per capita	26	2063	2208	526
Military capital	26	25716	15701	27843
Patents	26	280.3	244.0	95.2
Population	26	141550	134172	14392
Gas	26	6287	5327	2866

Figure 5: Descriptive statistics for long-run model, 1932-1957

One may speculate that the growing supply of ideas over time (proxied by the time trend) and the rivalry of smaller companies (proxied by the breakup variable) may have boosted the number of patents; and that the industry may have shifted resources from research back into production when growing income fueled a higher demand for oil-derived products. The speculations are crude; indeed, the breakup and time-trend variables correlate with one another, so one cannot be certain of disentangling their effects here. The equations in Figures 7 and 8 underestimate in the late 20s and early 30s, perhaps because they take no account of the growing auto market then.[12]

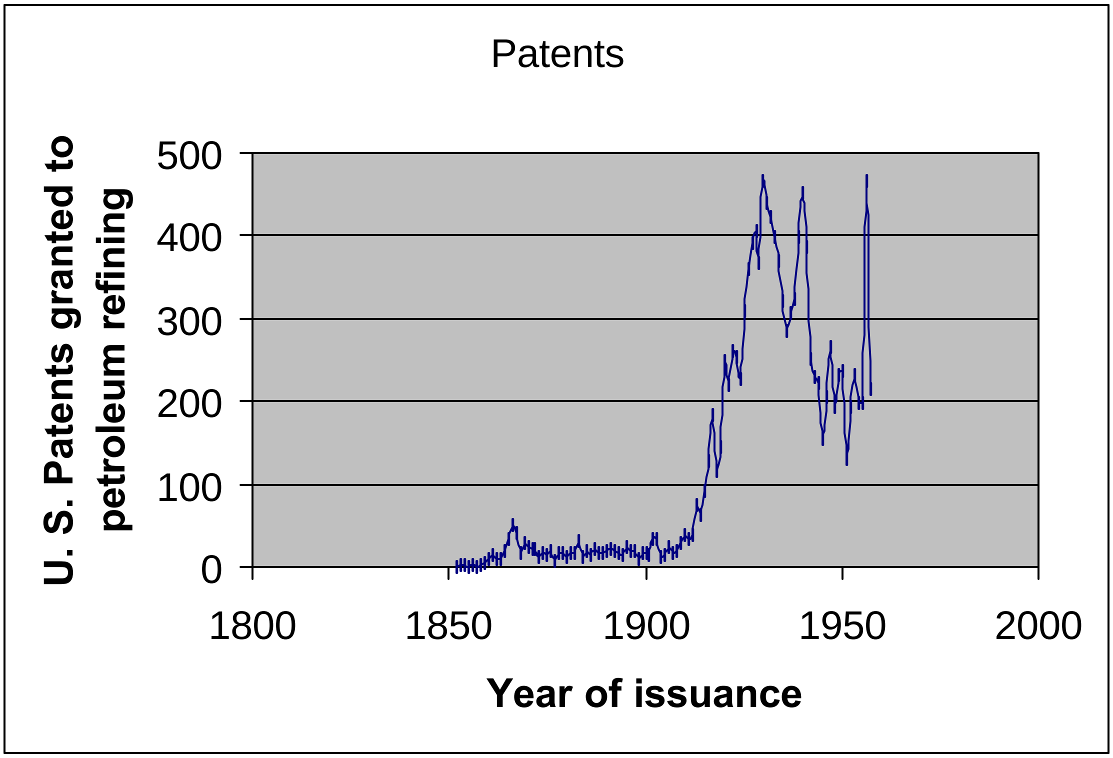

Figure 6: Patents granted

Patents = - 23718 + 12.7 Year - 0.295 Per capita income		
26 observations	Adjusted R^2 = .725	Durbin-Watson = .69
Variable	**Coefficient**	**Standard deviation**
Constant	-23718	2058
Year	12.664	1.099
Per capita income	-.29508	.03953

Figure 7: Long-run model

[12] Durbin-Watson tests suggest serial correlation in this and the following model, but the effects do not appear serious.

Patents = - 19597 + 10.5 Year + 71.7 Court - 0.262 Per capita income		
26 observations	Adjusted R^2 = .737	Durbin-Watson = .73
Variable	**Coefficient**	**Standard deviation**
Constant	-19597	2892
Year	10.469	1.542
Court	71.71	36.11
Per capita income	-0.26166	0.04218

Figure 8: Long-run model with breakup variable

The number of patents granted likely increases gently with real consumer spending on gasoline and motor oil in the same year. A rise in gas spending of $1 billion associates with a rise in the annual number of patents of 35 (Figure 9). Evaluated at the means, the point elasticity of patents with respect to gas spending is .79. Perhaps patents are granted quickly enough that inventors can accurately anticipate the demand for improvements in oil refining.

Patents may also increase in military spending and per capita income, but the links are not certain for data spanning 1932 through 1957 (Figure 9). Otherwise, the number of patents may diminish as time passes; one may ask whether this may represent growing market power in the oil refining industry.[13]

Patents = 37210 + 0.015 *Income per capita* + 0.0350 *Gas* + 0.00035 *Military capital* - 19.1 *Year*		
26 observations	Adjusted R^2 = .466	*Durbin-Watson* = 1.89
Variable	**Coefficient**	**Standard deviation**
Constant	37210	22084
Income per capita	0.0150	0.1457
Gas	0.03504	0.01477
Military capital	0.000348	0.001101
Year	-19.13	11.53

Figure 9: Long-run model with demand factors

[13] Durbin-Watson tests suggest serial independence in this and the following model.

Patents = 21673 - 10.7 *Year* + 0.00046 *Military capital* + 0.0448 *Gas* - 0.016 *Income per capita* - 0.00531 *Population*			
26 *observations*	*Adjusted* R^2 = .449	*Durbin-Watson* = 1.94	
Variable	**Coefficient**	**Standard deviation**	**VIF**
Constant	21673	33909	
Year	-10.75	18.03	95.3
Military capital	0.000458	0.001133	5.0
Gas	0.04476	0.02186	19.7
Income per capita	-0.0161	0.1564	33.9
Populate	-0.005312	0.008697	78.5

Figure 10: Expanded model of long-run

Controlling for population does not enhance the direct model's power to explain (as measured by adjusted R^2), and it introduces multicollinearity (as suggested by the variance inflation factors) (Figure 10). Perhaps, in patenting, oil-refinery firms consider direct market pressures, such as gasoline spending, rather than indirect pressures such as population growth.[14]

IV. Conclusions

Some evidence suggests that breaking up a monopoly may have stimulated innovation in oil refining, but only over the course of decades. In the shorter run, predictable demand factors, such as the immediate demand for crude oil, seem to spur more innovation than do more long-run factors, such as basic discoveries or a competitive market structure.

One demand factor that does seem to spur innovation in the longer run is gas spending. One may conjecture that competing firms may respond rapidly to "the smell of money" in a market of long and steady growth, such as that for gasoline and motor oil. They may obtain more patents to take advantage of higher demand for a related product.

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[14] In innovating and improving a process such as cracking, the oil refineries may also have substituted relatively cheap inputs, like raw materials, for costly labor (Enos, 1962).

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