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Damned If You Do, Damned If You Don't: The Paradox of Capital Market Responses to Steam Locomotive Dieselization Efforts

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Abstract

We examine stock market returns for the Big Three steam locomotive manufacturing firms from January of 1926 through January of 1960 and infer investor sentiment about efforts to transition from steam to diesel. We obtain paradoxical empirical evidence. In this period, Baldwin and ALCo shareholder wealth declined, while Lima's shareholder wealth grew about 2.8% per annum. These returns should have pushed management toward diesel. Experimentation was often associated with negative returns, discouraging a continuation of these efforts. With two exceptions, there were no efforts to force out the management teams that clung to steam locomotion – despite their abysmal performance.

Keywords: Technology Disruptive Innovation Paradox Response Capital Markets Event Study Steam Diesel Locomotive Baldwin ALCo Lima

Introduction

What lesson(s) can yet be learned from the displacement of steam by diesel locomotion that concluded over sixty years ago? The failure of the firms that dominated locomotive construction industry for over a century to successfully make the transition to diesel locomotion has been extensively studied[1]. What has been missing from these works is an analysis of what role, if any, capital markets played in encouraging or retarding the Big Three steam locomotive manufacturers (Big Three); Baldwin Locomotive Works (Baldwin), American Locomotive Company (ALCo), and Lima Locomotive Works Inc. (Lima), to transition from steam into diesel production.

Share Price Movements Lead Changes in Real Activity

In theory, upward movements' in common stock prices should drive capital toward the real economic activities that the firms have or will undertake. To see this, consider this simple example. A firm goes public and takes some of the cash it raised, engages in research and development and discovers a cure for the common cold. Upon learning of the development of this new drug, investors would be expected to incorporate the per share present value of the expected value of the monopoly profits to be earned at least through the life of the patents into the price of the firm's stock.

The rise in the innovator's share price would reduce its cost of capital through a reduction in the cost of equity capital. This would encourage the firm to undertake the investment necessary to produce the cold cure. The spike in the firm's share price would also gain the attention of investors/other firms and it would draw the attention of the market to the shareholder wealth enhancing activity (curing the common cold). This in turn would encourage other firms to invest in research and development to create a similar 'cold cure' and earn share a portion of the monopoly profits. Thus, increases in share price signal value creation opportunities and draw capital toward them.

[1] See Churella (1995) for and excellent treatments.

Conversely, a precipitous (idiosyncratic) decline in share price (a Q-ratio[2] less than 1.0) would signal the marketplace's belief that the firm's existing or proposed activities destroy shareholder value. Shareholder wealth-maximizing managers would scale back, eliminate, or call off the said activity. In the context of the example above, a firm that was producing 'cold remedies' prior to the innovation should see the price of their shares fall by the per share amount of the present value of the sales/profits lost to the innovator above. This would encourage the 'laggard' to scale back/abandon their obsolete activities and/or engage in R&D to create a rival to the 'cure'. This is how capital markets facilitate the 'creative destructive' process first described by Schumpeter (1942).

While the above example illustrates abrupt changes due to disruptive innovation, some innovations take a very long time (if ever) to influence real economic activity. The development of the diesel engine took place decades before its widespread usage in large locomotive models[3]. ALCo sold lightweight diesel switching engines as early as 1924, the Pennsylvania Railroad deployed a Baldwin diesel-switching engine in 1928, but the Big Three continued to be committed to steam-driven locomotives until 1949. While many behavioral theories have been put forward to explain why the Big Three dragged their feet[4], the role that capital markets may have played has not been explored.

In this paper, we compute risk-adjusted excess and market-adjusted monthly returns for the Big Three for fourteen announcements that took place from 1928 to 1956. We use this return evidence to infer if capital market reactions supported or discouraged their diesel locomotion experiments. We also looked at the long-term returns by shareholders of the Big Three during the thirty-four-year sample period in an effort to determine if or when share prices could be interpreted as signaling management to abandon steam and embrace diesel locomotion.

A brief history of the US Railroad Industry through the first quarter of the 20th Century

It is almost impossible now to appreciate today just how important railroads once were to the US economy and its development. The railroad industry traces back to 1826 when the Granite Railway incorporated as a common carrier, primarily to move stone from quarries in Quincy, to the site of the Bunker Hill Memorial in Charlestown, Massachusetts. Steam was the dominant form of locomotion almost from the very inception of the US railroad industry. In 1830, there was approximately 40 miles of track in the US, by 1870 this grew to over 50,000 miles. By the turn of the 20th century, there was almost 200,000 miles of track in the US and mileage would peak at 429,000 in 1929.[5]

[2] See Tobin and Brainaird (1976) for the development of this ratio and its relation to capital flows.

[3] Diesel locomotion supplanted steam in the lighter switch engine market by mid-1930s. The switcher engine market was the smaller than the market for passenger and freight locomotives. Engines build for the switcher market were significantly cheaper than the heavier models built for passenger and freight service. For more details, see Marx, (Spring 1976).

[4] See Sandberg and Wilson (2002), and Marre, "Lima: Too Little, Too Late," *Railfan & Railroad Magazine* (Winter 1974) for two excellent discussions.

[5] In contrast, in England there was 125 miles of track in place in 1830, which grew to 13,000 miles in 1870 and peaked at 22,000 in early part of the 20th century. See United States Census Bureau, *Report on Transportation Business in the United States at the Eleventh Census 1890*, p. 4 for US track mileage statistics and see Encyclopedia Britannica On-Line "British Railways" for track mileage in England.

Grants of land by the Federal government provided both the right-of-way and the asset base that allowed American railroads to attain the capital necessary to expand the network across the nation. In short order, railroads overtook canals and steamships as the most efficient and effective way to move both freight and passengers across the vast area of the United States. The financial claims of railroad companies dominated trading activity in both the stock and bond markets. To illustrate the importance of railroads in the late 19th century, the first stock index created by Charles Dow in 1884 contained just nine railroad stocks plus Western Union and the Pacific Mail Steamship Company[6].

With the railroad network in place, the United States experienced an industrial revolution and with it, the rise of large public corporations – many of which operate today. As a result, by the early 20th century, the largest firms in the US were no longer exclusively railroads. However, as of January 1926[7] the 61 listed railroad stocks had a combined market capitalization of $5.12B (19.1% of the total market capitalization)[8]. While the 1920's were arguably the pinnacle of rails, the automobile, trucks, and airplanes were already beginning their assault on their dominance of the US transportation market.

Electricity's Earlier Challenge to Steam

Before delving into the role that financial markets may have played in the dieselization of the locomotion industry, it is important to recognize that an earlier development of electrical locomotion did not overturn steam's dominance. The first underground electrical urban railroad was the City & South London Railway that opened in 1890[9]. By 1895, the Baltimore & Ohio Railroad employed three locomotives built by General Electric (GE) to move traffic through a long tunnel in the city of Baltimore[10].

The demand for electric locomotion increased as more urban areas struggled with air-quality and safety issues that arose from the growth in commuter rail services. As the result of a passenger train accident[11] that arose due to obstructed views from the steam and smoke exhaust of other steam locomotives, New York City adopted *The Grand City Law* May 7,

[6] The initial Dow Jones Industrial Average (DJIA) was created in 1890 and it consisted of 12 stocks. No stock has been continuously part of the DJIA from the beginning, but General Electric (just recently dropped) was an original member and has been in the index since 1907. The DJIA subsequently expanded to 30 stocks and the Dow Jones Railroad Index (now DJ Transportation Index) has shrunk in importance and visibility. See S&P Dow Jones Indices (us.spindices.com) for more information.

[7] The beginning monthly stock market data availability from the Center for Research in Security Prices (CRSP).

[8] The largest railroad, Pennsylvania Railroad (PRR) had the 7th largest market capitalization with $506M, the New York Central Railroad was 9th ($486M) and the Canadian Pacific Railroad was 10th with a market capitalization of $404M. Fourteen of the 50 most valuable listed stocks were railroads. There were 514 stocks listed on the NYSE and ASE in January 1926 with a total market capitalization of $26.8B.

[9] See Badsey-Ellis, Anthony (2005) p. 36.

[10] Because of the piece-meal way in which railroads developed, many large urban centers with active port facilities were served by multiple independent railroads that terminated their service in these cities. Subsequently, mergers and acquisitions created larger integrated railroads, but this did not necessarily yield direct paths through these cities.

[11] The accident 15 passengers when a train missed a stop signal and rear-ended a stopped train in crowded Grand Central Station. See *New York Times* "Fifteen Killed in Rear End Collision," January 9, 1902.

1903 that outlawed steam locomotives for passenger service in Manhattan. The legislation was to go into effect no later than 1908[12].

At the time, electrification was the only feasible alternative to steam locomotion. By 1904, ALCo combined with GE, and Baldwin combined with Westinghouse to produce the first electric locomotives designed for passenger service to meet the new restrictions in New York City. Although more urban areas adopted similar legislation, steam locomotion remained firmly entrenched for moving freight, moving passengers over long distances between major urban markets, and providing switching services in railyards. According to Morgan (1970),[13] electrification peaked sometime in the early 1930s at roughly 3,100 miles, which would have been less than 1% of track mileage in the US[14].

Despite GE's size advantage and its greater access to financial capital, electrification failed to supplant steam. Through the end of WWII, GE and Westinghouse were seemingly satisfied with being the dominant supplier of components and systems. In 1948, Westinghouse bought a 21% stake in Baldwin, providing needed working capital to prop up an important customer – but they never entered the locomotive market. It wasn't until after GE grew tired of ALCo slow progress with diesel, that they ended their partnership by 1954 and began producing diesel locomotives on its own.

The lesson that the management of the Big Three likely learned in the early 20th century was that by entering into supply contracts and/or a strategic partnership with a larger potential entrant, you could forestall their direct entry almost indefinitely. Using GE and Westinghouse equipment mitigated the need for the Big Three to engage in electric system R&D. However, this retarded their ability to develop their own expertise – which held them back when they tried to fully commit to diesel. None of the Big Three looked to be vertically integrated with electrical equipment suppliers. However, in light of their experience with GE and Westinghouse, it is not surprising that the Big Three tried to follow the same basic strategy when dealing with General Motors (GM). Unfortunately, for the Big Three, GM did not follow the GE/Westinghouse playbook when dealing with them.

The Locomotion Industry in the Early 20th Century

By 1926, the locomotive manufacturing industry had essentially been operating as a three-firm oligopoly for about twenty years. The original dominate firm in the industry was Baldwin Locomotive Works, which could trace its beginnings back to 1825.[15] Baldwin survived numerous panics, thrived during the Civil War, and emerged as the leading US locomotive manufacturing firm at the turn of the century. Ownership of Baldwin was

[12] The Electrification Law (also known as the Kaufman Act) of 1923 extended the ban (effect January 1, 1926) to all of New York, Mount Vernon, and Yonkers. See Brennan (2001).

[13] See Morgan (1970), p. 44-47.

[14] Electrified track mileage was less than 1,800 miles in the US and it is mostly on the East Coast. For more details see Morgan (1970). It is worth noting that approximately one-third of railroad track mileage in England is electrified.

[15] Mathias Baldwin formed a partnership in 1825 to build book binding machinery, which evolved into building a working model of the famous Tom Thumb engine (in England), which led to the Baldwin being contracted to build a working locomotive ('Old Ironsides') which went into service in 1832. See *History of the Baldwin Locomotive Works, 1831-1920*.

transferred through a series of partnerships until 1909 when it was incorporated. In January of 1926, Baldwin had a market capitalization of $21.4M (ranked 207th, which is $300M in 2018 dollars).

Samuel Vauclain was the dominant figure at Baldwin for decades. He joined the firm in the 1880s and rose through the management ranks. He joined the Board of Directors in 1896, served as President from 1919 to 1929, and as Chairman of the Board until his death in 1940. Vauclain patented a significant improvement to steam locomotion in 1889 and he had a life-long distain for diesel locomotion. He would champion the construction of a new manufacturing facility in Eddystone that tripled the firm's productive capacity. Unfortunately, the new plant came online in 1928 just as business activity slumped and the increased debt service drove Baldwin into receivership in 1934.

The old railroad yard/production site at Broad Street in downtown Philadelphia was seen as very valuable real estate prior to the Great Depression. Speculation about the sale of the site was used by syndicates to push Baldwin's common stock price to unprecedented levels by activities that are now highly illegal. After these syndicates earned sufficient profits from under-informed investors, they continued their publicity campaigns while liquidating their positions. Once they ceased their buying activity, the shares of Baldwin plummeted in price. This manipulation no doubt impeded the ability of the firm to raise equity capital, pay down their debts and avoid receivership in 1934.[16]

The American Locomotive Company was born through a consolidation of eight small locomotive firms in 1901, and it consolidated production in Schenectady, NY. In 1904 the firm bought the largest locomotive manufacturer in Canada and in 1905 it acquired the Rogers Locomotive (then second only to Baldwin). Ultimately, ALCo came to capture over 40% of the market by 1920s. While ALCo started well behind Baldwin, by January of 1926 had a market capitalization of $52M (ranked 118th $731M in 2018 dollars).

While the management at ALCo in the early part of the 20th century was committed to steam locomotion, they were more open to diesel experimentation than either Baldwin or Lima. ALCo developed a successful diesel engine for the switching market and dominated this segment of the industry for a decade. However, management never saw diesel as anything other than an adjunct technology – unlike the management of GM which ultimate saw diesel as a replacement technology.

Lima Locomotive Works traces its beginnings back to 1878 in the city of Lima, Ohio. The relatively small Ohio-based firm never had the resources to seriously challenged Baldwin or ALCo's dominance of the industry. Early on, they found a profitable niche producing geared locomotive for cogged railroads that served loggers and quarry operators.

In the early 1920s, Lima's fortunes improved with the development of a 'super charged' engine that had significantly more power and speed than their existing locomotives. While this improved the sales and profitability of the firm, they were not able press home their technological advantage to challenge ALCo and Baldwin. In January of 1926, Lima had a market capitalization of $12.7M ($178.5M in 2018 dollars) which ranked 280th of the 514 firms listed on the NYSE and ASE at that time.

[16] The manipulation of Baldwin Locomotive Works common stock by Arthur Cutten reported netted him $10 million and it was described in the *New York Times* "Millions in Profits Attributed to Cutten" Sept. 11, 1928.

In 1930, with automobile sales falling, GM acquired the Winton Engine Company (Winton), a manufacturer of diesel engines, reportedly because they were looking to gain access to the firm's research & development/intellectual property for use in the automobile market. More as an after-thought and to keep Winton busy, GM acquired the Electro-Motive Company (EM) – the biggest customer of Winton, also in 1930. EM had been struggling to compete with GE and Westinghouse in the electric locomotive market. EM did not have any manufacturing facilities or the financial resources necessary to develop a diesel-electric locomotive on its own, so they welcomed GM's buyout.

It wasn't until 1933 that EM produced a diesel locomotive for Burlington Northern Railroad. The initial results of the engine trials between Chicago and Denver were outstanding. When put into regular service between Kansas City and Lincoln, Nebraska the locomotive achieved higher speeds and lower costs than the steam locomotives that it replaced. Importantly, the diesel engine did not require water to operate – something that interested railroads in the far west.

After this highly publicized demonstration of the efficacy of diesels in the passenger market (they were already dominating the lightweight switcher engine market), there was more interest in diesel locomotion from railroad managers. Buoyed by success, GM announced in February of 1935 that it was building a new diesel locomotive manufacturing facility outside of Chicago. Rather than join one or more of the Big Three to develop diesel's capabilities, GM opted to go it alone.

Critical to GM's long-term success was understanding that the railroad industry was being pummeled by the Great Depression and that their managers were increasingly coming from finance, not from operations. GM made the conscious decision to promote the cost savings/efficiency features of its new diesel engines to the financial managers. GM further reduced the risk to buyers by providing warranties. GM rejected the small-batch/customized approach to production used by the Big Three and adopted the standardized production techniques typical of the automobile industry. This helped to bring down the relative cost of diesel engines, helping to make the transition economically feasible.

The Big Three's Response to the Diesel Threat

Many aspects of the dieselization of the locomotive industry have been studied. In hindsight, the failure of the Big Three to understand the serious nature of the diesel threat to the steam locomotion seems inconceivable. It would be easy to understand the failure to understand the Big Three's failure to grasp their vulnerability had the diesel technological jolt been 'sudden' or if the management of the Big Three was lacking in ability – but neither is true appears to be true.

Of the many works that address the failure of the Big Three, two are reviewed here. Churella (1996) argues that customer loyalty by the senior railroad managers to steam locomotion, except for lightweight switching engines, discouraged the Big Three steam locomotive manufacturers from a serious exploration of diesel technology. While this might explain the behavior of East Coast railroads who were close to coal supplies and for whom coal, was a significant source of freight revenue, it does not describe the behavior of West Coast who spent millions of dollars to provide water for steam generation across the arid west and southwest.

Marx (1976) puts forward the hypothesis that the Big Three steam locomotive manufacturers were unable to fully embrace the diesel technology before WWII because of their large investments in steam locomotion[17] and a lack of competition. Marx further argues that the L-97 ruling by the War Production Board on April 4, 1942 provided General Motors the sole authority to produce large diesel-powered locomotives. This decision appears to be entirely based on the fact that GM had the only proven diesel product outside of the lightweight switcher market.

By the time, the war was over; GM had delivered over 1000 diesel locomotives to the Navy and produced another 2000 diesel engines for LSTs that were virtually identical to those installed in trains. As seen in Table One, GM's revenue from producing diesel engines and generators during WWII exceeded the value of steam locomotives produced by any of the Big Three. GM used this experience to build huge technological advantage in diesel engines coming out of WWII.

Almost immediately following WWII GM overtook the Big Three in the sales of locomotives. In June of 1949, the last steam engine produced for domestic use in the US. Westinghouse injected capital in Baldwin in 1948 in an effort to prop up their transition to diesel locomotion. Under new leadership by a former Westinghouse VP, Baldwin merged with Lima in an effort to make better use of production capacity – it didn't work. By 1956 Baldwin-Lima-Hamilton announced it was abandoning locomotive production altogether. ALCo produced locomotives in the US until 1969. By 1960, US railroads had fewer than 300 steam locomotives in operation. The dieselization of America's railroads was essentially complete in less than fifteen years – achieved by two firms that never build a single steam locomotive.

Description of Empirical Method

We employ two traditional event study methods to examine the response of marketplace to the public announcement of new information. First, we compute risk-adjusted abnormal returns. We construct an expected return for the common stock of the firm(s) of interest by making use a single-index or market model[18]. This requires the estimate of the firm(s)'s systematic risk (i.e. beta), and this is usually done in a pre-event window which does not contain a similar information release(s). Standard practice uses sixty observations to estimate systematic risk.

When using monthly data, sixty observations is five years of observations – whereas when one used daily data it is approximately three months. We have identified fourteen events that we believe are worthy of examination in this thirty-four-year period – the longest time-period between the events is five years, five months, but most are separated by more than two years. Thus, we estimate the firm's systematic risk (and an intercept coefficient) using twenty-four monthly returns that end two-month prior to the announcement of interest. We use the return on the Equally-Weighted CRSP index as a proxy for the return on the market portfolio.

We estimate expected returns in the month prior to event and in the month of the information release with: ER = a + B(RM), where ER is the expected return, a is the intercept estimate, B is the slope estimate, and RM is the Equally-Weighted CRSP index return in the respective

[17] Essentially, they suffered from the so-called 'sunk cost fallacy' as described by Arkes and Blumere (1985).

[18] Other methods also exist, for brevity we limit our discussion to the most prevalent event study method.

months. We subtract the ER from the actual returns for the Big Three to obtain an unexpected/abnormal return.[19] We report results in Table Two.

Second, we compute monthly market-adjusted excess returns by subtracting the Equally-Weighted CRSP return (with dividends), as a proxy for the return on the market, from the holding period returns (with dividends) of the Big Three steam locomotive manufacturers for each month in the sample period. What is substantially different about this historical study is that it employs monthly data[20] and we examine multiple events in a long time-period: January of 1926 to January of 1960. We report these results in Table Two.

Lastly, we compute wealth-relative measures for each of the Big Three plus the CRSP Equally-Weighted Index. A wealth-relative measure[21] is computed as follows: WR = □□(1 + R), where WR is a measure of shareholder's wealth relative to the starting point, □□is a product operator, and R is the rate of return earned by stockholders (including dividends) in the month. These results are reported in Table Three.

Discussion of Empirical Results

We identified fourteen events[22] that were likely to have a significant impact on the value of at least one of the Big Three during the twenty-four-year sample period. Because of the oligopolistic nature of the steam locomotive manufacturing industry, most of the firm specific events influenced the other two members of the industry, but to a lesser extent.

It is important to note that short estimation period for the market model, led to large values for the standard error of the estimate. This made it difficult to obtain statistical significance for many abnormal return measures (reported in Table One). However, average month returns to the Big Three stockholders were just a little bit greater than 1% per month. Thus, in most cases the announcement effects would have been economically significant to the Big Three's investors.

Likewise, the standard deviation of monthly market-adjusted returns was quite high (over 10% per month for each of the Big Three). This makes it difficult to find market-adjusted returns that are statistically different from zero. We note that the mean monthly market-adjusted returns were -0.05%, -0.04%, and -0.03% for Baldwin, ALCo, and Lima,

[19] For example, if the pre-event regression yielded intercept and Beta of .01 and 1.2, respectively, and the return on the Equally-Weighted CRSP index was 5% in the month prior to an event, the expected return for the firm would be equal to: 1% + 1.2*(5%) = 7%. If the firm's actual return in the month prior to the event was only 4%, the abnormal return measure would be equal to -3%.

[20] Daily machine-readable stock return data from CRSP is available from July of 1962. As noted previously, monthly stock return data is available from January 1926. The first so-called 'event study' by Fama, Fisher, Jensen and Roll, (1976) employed monthly data and a five-year estimation window to examine stock market reactions to stock split announcements.

[21]To illustrate, January 1926 is the starting point of our analysis and all Big Three firms and the CRSP Equally-Weighted index wealth-relative measures are set to 1.0. If Lima's stockholders earned +10% in January, the WR index would be equal to 1.0 X (1.1) = 1.1 at the end of January. If Lima's stockholders earned +5% in February, the WR would be equal to 1.0 X (1.1) X (1.05) = 1.155, meaning that their stockholders were 15.5% more wealthy than they were on January 1, 1926. Finally, if Lima's stockholders lost 8% in March, the WR would be equal to 1.0 X (1.1) X (1.05) X (.92) = 1.0626, meaning there were now only 6.26% wealthier than they were on January 1, 1926.

[22] Many of these events are described in a so-called 'work in progress document' by Baer (2004-2011).

respectively. Thus, many of the market-adjusted returns will be economically significant but not statistically significant.

When examining the announcement effects, what immediately stands out is a paradox when the Big Three experimented with diesel production. When Baldwin announced delivery of a test diesel locomotive to the Pennsylvania Railroad in 1928, the market response was negative and significant. Interestingly, Lima's abnormal return was slightly positive (Table Two), but the market-adjusted return was negative (Table Three). ALCo responded negatively to the Baldwin announcement. This response would discourage Baldwin management from further experimentation with diesel locomotion.

In 1931 ALCo announced the delivery of a diesel switcher and the market's response was positive (Table Two) and significant (Table Three). This should have encouraged ALCo to continue developing diesel locomotion. However, when ALCo announced a partnership with GE in response to the growing success of EM/GM in 1941, the response was negative (Table Three). Conversely, the negative response by Baldwin stockholders to the ALCo/GE partnership announcement should have nudged them to step up their diesel locomotion effort.

The announcement by GM that it was going to build a diesel engine facility in February of 1931 was just a few days before Baldwin announced that it had missed an interest payment on bonds and that it was seeking protection from its creditors in receivership. All the Big Three firms experienced statistically significant declines (Table Two and Three) – Baldwin's was by the far the most negative. Interestingly, Baldwin's announcement in 1938 it was leaving receivership has also associated with negative shareholder responses to all of the Big Three (Table Two and Three).

The L-97 ruling by the War Production Board in February of 1942 basically froze out the Big Three from further diesel development, leaving GM with a virtual monopoly in diesel locomotion. This announcement was associated with negative market responses (Table Two and Three). This is strong evidence that the market realized that the Big Three were going to lose more ground to GM in the development of diesel for the (unknown) duration of WWII.

Ironically, there was a rebound in domestic and international orders for steam locomotives during WWII. This was partly a result of the need to use petroleum-based products to fuel the war effort (making diesel operation a bit of a luxury), and partly because GM was producing war materials in such quantities that they were unable to meet the demand for locomotives. Thus, rather heeding the market's signal in 1942 that diesel was important, the management of the Big Three was made more confident about the future of steam locomotion.

Following the end of WWII, the demand for steam locomotion collapsed. We examine several belated efforts by the Big Three to the sudden shift toward diesel locomotion. In 1947, Lima's merger with General Machinery gave them diesel engine capabilities. This was met with a positive response (Tables Two and Three), and the lagging Baldwin also experienced negative returns.

The announcement by ALCo that it was ending the production of steam locomotives in 1947 was greeted with positive returns. The end of steam locomotive production at Lima in 1948 produced a negative and significant response (Tables Two and Three) – primarily because Lima still did not yet have a viable diesel product. Later in 1948 when the last of the Big

Three, Baldwin, ended steam locomotive production, the market reaction was virtually zero: it was not a surprise – there hadn't been an order by a domestic railroad for a steam engine for more than a year.

When Westinghouse made a $17M investment (obtaining a 21% voting stake) in Baldwin in mid-1948, it was widely reported that it was to provide the firm with working capital. Baldwin was already a customer of Westinghouse and it did not signal an increased interest in diesel technology. Nonetheless, there was a positive response in the stock market to the announcement. The responses at ALCo and Lima were mixed (positive abnormal returns, negative market-adjusted returns). Westinghouse installed VP Marvin Smith as President of Baldwin in May 1949 to help save this important customer.

The new Baldwin management team decided to merge with Lima-Hamilton. The market responded with positive and significant returns to Baldwin (Table Two and Three). This enthusiasm turned out to be a pipe dream. By 1953, Westinghouse was exiting the locomotive component market and Baldwin-Lima-Hamilton resumed using GE equipment before abandoning the locomotive production in 1956. That announcement was bad news for ALCo shareholders who now left to go it alone against EM/GM and GE – who had entered the locomotive production market by this date.

To illustrate the cumulative impact of the Big Three's management policies on shareholder wealth, we compute wealth-relatives for the three firms and compare them to the wealth-relative for the CRSP Equally-Weighted index. These results are reported in Table Four. For example, the first entry in Table Four is interpreted as follows: a single dollar that had been invested in Baldwin, ALCo, Lima, and EW Index in January 1926 turned into $2.3687, $1.0013, $0.7120, and $1.6601, by September of 1928, respectively. Wealth-relative measures rise (fall) when the return to stockholders is positive (negative).

While Baldwin experienced a negative return when they deployed the experimental diesel switcher at PRR in 1928, the other two firms increased in value. This should have discouraged Baldwin from further experimentation. The responses at ALCo and Lima also discouraged experimentation – they were 'rewarded' for not having a similar diesel experiment. But, when ALCo started providing diesel switchers in 1931, the returns for all the Big Three were negative. In some respects, the response to the 1931 announcement suggests investors were worried that ALCo was 'breaking' the cartel (of steam locomotion). The announcement in 1941 that ALCo was going to partner with GE to produce diesel locomotives led to negative returns to ALCo and Baldwin. In summary, the market did not uniformly reward the Big Three for their early experiments with diesel locomotion.

Continuing the analysis, the original dollar invested in Baldwin in January of 1926 had declined to just $0.0679 at the end of February 1935, the month that they declared bankruptcy and GM announced it was building a manufacturing facility outside of Chicago. For comparison, ALCo had declined to $0.1718 and Lima had declined to $0.2950, but a dollar invested in the CRSP Equally-Weighted index had rebounded from a huge decline at the start of the Great Depression and it was back up to $1.2578. Clearly, the announced entry by the much larger GM into the locomotive market was bad news for the shareholders of the Big Three.

The War Production Board L–97 order basically locked the Big Three into the production of steam locomotives, except ALCo who could produce diesel-switching engines. This

announcement led to negative returns for all of the Big Three. While they could not act on the signal, this response clearly suggests the market saw the freeze out of the Big Three from the diesel market as bad news.

The wealth relatives of the Big Three after the L-97 ruling by the War Production Board were just about at their all-time lows. However, all of the Big Three received substantial contracts for war materials (see Table One) and the demand for steam locomotives temporarily rebounded. At the end of WWII, each of the Big Three had more than tripled from their post-L-97 ruling lows. However, almost immediately following WWII, GM catapulted to the top of the industry and demand for steam locomotives collapsed.

When ALCo exited the steam locomotive business in June of 1948, the original dollar invested in the firm in January of 1926 was worth just $0.4348, but a dollar invested in the CRSP Equally-Weighted Index was worth $11.103. Lima was the next to exit in May of 1949, and they had declined in value by almost 40% for the highs they achieved following their acquisition of diesel engine manufacturer. By the time that Baldwin produced the last steam locomotive for a domestic railroad in September of 1949, the original dollar invested in the firm in January of 1926 had declined to just $0.1363. During the same time-period, a dollar invested in the CRSP Equally-Weighted index was worth $10.348. In summary, the long-term consequences of sticking with the production of steam locomotives on shareholder wealth of the Big Three firms were devastating.

Post-WWII mergers and alliances by members of the Big Three drew mixed results. Baldwin increased in value when Westinghouse came to the rescue in 1948. They rose again (sharply) on the news that they were buying Lima-Hamilton. Ultimately, these actions did not save Baldwin – they shut their locomotive unit in June 1956 after nearly 125 years of production – most of which time they were the market-leading firm in the US. Lima's merger with General Machinery in 1947 that created Lima-Hamilton was greeted with negative returns. This could have been because of the price paid to belated enter the diesel engine business, rather than an assessment of the future of diesel locomotion.

Conclusion

Movements in a firm's share prices can signal investor's beliefs about the efficacy of its strategy and activities and help drive capital to real activities when share prices rise, and away from activities when share prices fall. We examine capital market evidence from 1926 to 1960 for the Big Three steam locomotive manufacturing firms to determine if investors signaled a concern about the long-term viability of steam locomotion and if they understood the threat that diesel locomotion posed. The empirical evidence is mixed.

The values of the Big Three lagged far behind a broadly diversified stock portfolio during the period of analysis. The wealth consequences of sticking with a steam locomotion strategy are striking. What is hard to understand is why shareholders did not press for changes in management that would have been more favorable to the adoption and/or development of

diesel[23]. While contests for corporate control were less frequent in the middle of the 20th century, there were not unheard of.[24]

An examination of share price response to diesel experimentation was almost always associated with negative returns to the innovator. This is paradoxical – the Big Three's common stock values were shrinking due to their continued reliance on steam locomotion, and yet most of the response to their diesel experimentation would have discouraged further innovation. Only ALCo seemed to have been rewarded for diesel innovation, but the firm never saw diesel as a serious replacement for steam until well after WWII. ALCo's foregone R&D in diesel locomotion left it with inferior product offerings when the demand for steam locomotion collapsed.

Our findings are limited to one industry and obtained over a particularly long period of time, but they suggest the need for further study of role of capital markets when disruptive technologies are developed. In this case, we find that investors did not fully appreciate the risks posed by the development of diesel locomotion to the long-time manufacturers of steam engines, particularly in diesel's infancy. This inability of financial markets to see the true potential of diesel's disruptive impact helps to explain the role that venture capital funds/private capital play in the development of new technologies. Better understanding whether financial markets aid or impede the spread of technological innovation and 'creative destruction' process first described by Schumpeter (1942) is perhaps even more critical today when the time-span/life-cycle of new technologies is dramatically shorter than the two decades it took for diesel to supplant steam locomotion in the US.

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[23] Westinghouse did put a new management team in place after its investment in Baldwin in 1948, but they soon exited the market for supplying electrical systems for locomotives – so their interest may have waned. In some respects, the technology gap was too large for Westinghouse to save Baldwin in their battle against GM and GE.

[24] The success of Robert Young in unseating the management of the New York Central Railroad in early 1954 is particularly instructive. See Brooks, "The Great Proxy Fight," in *The New Yorker* July 3, 1954, p. 28

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TABLE ONE
War Production Board Contracts 1940-45 (in $000)

Firm	Total War Contracts	Locomotive Contracts			Diesel Engines
		Steam	Diesel	Electric	
Baldwin	560,085	207,415	6,551	157	20,021
ALCo	935,332	193,321	11,585		7,725
Lima	209,890	55,952			
Big Three	1,705,307	456,688	18,136	157	27,745
GE	3,237,737		13,817	2,267	30,153
GM	12,817,440		2,608		258,885
GE+GM	16,055,177		16,425	2,267	289,038

TABLE TWO
Risk-Adjusted Abnormal Returns
Month of Announcement and the Month before Announcement

Dates / Event	Baldwin	ALCo	Lima
10/27	-12.83%	2.20%	2.35%
10/28 Baldwin diesel deployed at PRR	- 8.60% ***	-2.64%	0.05%
6/31	8.22%	23.66%	20.03%
7/31 ALCo diesel switcher to NJRR	-10.45%	-3.11%***	4.99%****
1/35	2.91%	-7.38%	-9.72%
2/35 Baldwin Bankruptcy / GM plant	-61.28%**	-7.98%	-19.94%****
8/38	-0.88%	0.12%	-5.45%
9/38 Baldwin Leaves Bankruptcy	-4.54%	-2.12%	-0.22%
2/41	0.84%	-3.50%	2.67%
3/41 ALCo switcher with GE	-7.40%	3.87%	-0.52%
3/42	-6.96%	-5.64%	-5.28%
4/42 War Production Bureau L-97	-9.45%***	-3.59%	-3.63%
7/45	-3.10%	-4.57%	-5.87%
8/45 End of WWII	2.27%	3.08%	4.26%
7/47	-1.41%	5.24%	4.61%
8/47 Lima merger with Gen. Mach.	-4.26%***	-2.26%****	-2.35%
5/48	4.54%	9.92%	11.54%
6/48 Last Steam at ALCo*	-0.45%	0.05%***	0.97%***
6/48	0.02%	-1.37%	-0.04%
7/48 Westinghouse/Baldwin	11.75%***	-2.39%	-1.35%
4/49	-4.35%	-0.44%	1.87%
5/49 Last Steam at Lima	-2.98%****	-3.42%	0.10%
8/49	-1.90%	-1.24%	0.92%
9/49 Last Steam at Baldwin	0.79%	5.74%	5.50%
6/50	5.46%	-8.70%	-8.22%
7/50 Baldwin to merge @ Lima	34.72%*	-0.45%***	0.59%****
5/56	0.63%	-1.90%	
6/56 Baldwin Ends Diesel	0.69%	-5.08%***	

Note: the average month return for Baldwin, ALCo and Lima were 1.36%, 1.05%, and 1.12%, respectively

TABLE THREE
Two-Month Cumulative Market-Adjusted Abnormal Returns

Dates or Event	Baldwin Market-Adjusted Abnormal Return	ALCo Market-Adjusted Abnormal Return	Lima Market-Adjusted Abnormal Return
10/28 Baldwin diesel deployed at PRR	-17.35%	-8.71%	-3.25%
7/31 ALCo diesel switcher delivered	-2.78%	5.62%	-3.31%
2/35 Baldwin Bankruptcy / GM plant	-62.50%*	-24.79%***	-18.20%***
9/38 Baldwin Leaves Bankruptcy	-8.61%	-6.28%	-6.67%
3/41 ALCo switcher with GE	-5.16%	-5.01%	-4.89%
4/42 War Production Bureau L-97	-12.48%	-6.05%	-9.05%
8/45 End of WWII	0.09%	4.06%	-.1.02%
8/47 Lima merger with Hamilton	-8.30%	-1.31%	8.32%
6/48 Last Steam at ALCo	2.37%	1.68%	-1.97%
7/48 Westinghouse/Baldwin	6.86%	-5.58%	-6.11%
5/49 Last Steam at Lima	-13.43%	-9.81%	-16.66%***
9/49 Last Steam at Baldwin	-1.73%	2.52%	-0.06%
7/50 Baldwin to merge @ Lima	35.13%***	15.35%****	1.98%****
6/56 Baldwin ends Diesel	-8.15%	-7.31%	NA

*Significant at the 5% level
**Significant at the 10% level
***Significant at the 15% level
****Significant at the 20% level

Note: the average market-adjusted return for Baldwin, ALCo, and Lima were -0.05%, -0.04%, and -0.03%,

TABLE FOUR
Wealth Relatives of the Big Three Steam Locomotive and CRSP Equally-Weighted (EW) Index at various dates

Dates or Event	Baldwin Wealth Relative	ALCo Wealth Relative	Lima Wealth Relative	EW Wealth Relative
1/26	1.0000	1.0000	1.0000	1.0000
9/28	2.3687	1.0013	0.7120	1.6601
10/28 Baldwin diesel deployed at PRR	2.2206	1.0217	0.7737	1.6891
6/31	0.6017	0.2466	0.4796	0.8421
7/31 ALCo diesel switcher delivered	0.4852	0.2288	0.4300	0.7830
1/35	0.2183	0.2263	0.3738	1.3324
2/35 Baldwin Bankruptcy / GM plant	0.0679	0.1718	0.2950	1.2578
8/38	0.0733	0.2511	0.5791	2.2129
9/38 Baldwin Leaves Bankruptcy	0.0693	0.2511	0.5478	2.1805
2/41	0.1235	0.1784	0.4681	2.3266
3/41 ALCo switcher with GE	0.1185	0.1718	0.4826	2.3598
3/42	0.0984	0.1107	0.6285	2.3072
4/42 War Production Bureau L-97	0.0864	0.1008	0.5299	2.2005
7/45	0.2805	0.4758	1.3572	8.0262
8/45 End of WWII	0.3065	0.5440	1.4408	8.5553
7/47	0.2138	0.3743	1.5309	9.6573
8/47 Lima merger with Gen. Mach.	0.1966	0.3619	1.5150	9.4915
5/48	0.1946	0.4364	2.0336	11.244
6/48 Last Steam at ALCo	0.1887	0.4338	1.9981	11.103
7/48 Westinghouse/Baldwin	0.1948	0.3834	1.7783	10.506
4/49	0.1394	0.2785	1.3871	9.5898
5/49 Last Steam at Lima	0.1246	0.2576	1.2190	9.1740
8/49	0.1295	0.2764	1.3930	9.9193
9/49 Last Steam at Baldwin	0.1363	0.2735	1.3973	10.348
6/50	0.1411	0.2820	1.4552	12.258
7/50 Baldwin to merge @ Lima	0.1968	0.3416	1.7323	12.879
5/56	0.4445	0.6673	1.9931	38.140
6/56 Baldwin Ends Diesel	0.3877	0.6412		38.968
1/60	0.4667	0.6873		60.457

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