Mergers as Reallocation

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Abstract

We model merger waves as reallocation waves, and argue that mergers spread new technology in a way that is similar to that of the entry and exit of firms. We focus on two periods: 1890-1930 during which electricity and the internal combustion engine spread through the U.S. economy, and 1970-2000 – the Information Age. As the model implies, reallocation did rise during both epochs. The model also implies that exits should lead mergers during a transition, but this seems to have happened only in the electrification epoch. (JEL E3, O3, O4)

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1 Introduction

Evidence shows that changes in asset ownership through mergers shift resources to more efficient uses and to better managers. Harris, Siegel, and Wright (2005) find that TFP rises after a company is taken over, and that this seems to occur because the new entity outsources some operations and thereby economizes on labor. It is probable that a firm's new management would effect such changes by using new technologies better, and this is the hypothesis that we pursue here. We shall posit that a merger can shift the control of assets to managers that can better handle a new technology. When that new technology is a General Purpose Technology (GPT), the pressure to adopt the GPT may create a merger wave. The wave will then be efficiency enhancing as well as innovation enhancing.

This paper adds two things to the literature. First, it reports patterns in a data set that we have put together from existing and from original sources, including data on mergers and stock market exits for the pre-CRSP period from 1885 to 1925. These data allow us to compare two technological revolutions and the role that mergers played in those periods. Second, the paper describes a general equilibrium model in which mergers help usher in a new GPT.

Our data are limited to stock-market transactions. Over the twentieth century, stock-market capitalization rose by a factor of ten, from 17 percent of GDP in 1900 to 178 percent of GDP in 2000. The reallocation we measure is thus a rising fraction of economy-wide reallocation, and the Modigliani-Miller theorem says that this fall in the debt-equity ratio should not have affected reallocation activity in the economy at large. We shall assume, then, that the relative amount of reallocation that we detect among publicly-traded firms is the same as the extent of economy-wide reallocation relative to the economy as a whole. Accordingly, Figure 1 reports the stock market value of the reallocated capital as a percentage of the value of all publicly-traded capital.

The U-shaped line in the upper panel of Figure 1 is our estimate of the total amount of capital that has been reallocated on the U.S. stock market since 1890. Its components are the stock market capitalizations of exiting firms and merger targets. Exits, given by the center line, are a rough measure of how much capital exits from the stock market and comes back in under different ownership, or at least under a different name. The line in the lower panel is the stock-market value of merger targets. Appendix A describes the data sources and methods. Two GPT eras, Electrification and IT, are shaded. The beginning dates of these two epochs – the startup of the Niagara Falls power facility in 1894 and Intel's invention of the 4004 chip in 1971 – are perhaps debatable; in Jovanovic and Rousseau (2005) we justify the dates based on the point in time when each GPT achieved a one-percent diffusion in the median sector. Similarly, we say that the era is over when the respective diffusion curves flatten out. For Electrification, it takes until about 1929 for net adoption in manufacturing to reach a plateau, whereas new adoption of IT was still rising in 2003 so that, on that criterion, the IT epoch continues. If one accepts the dating implied

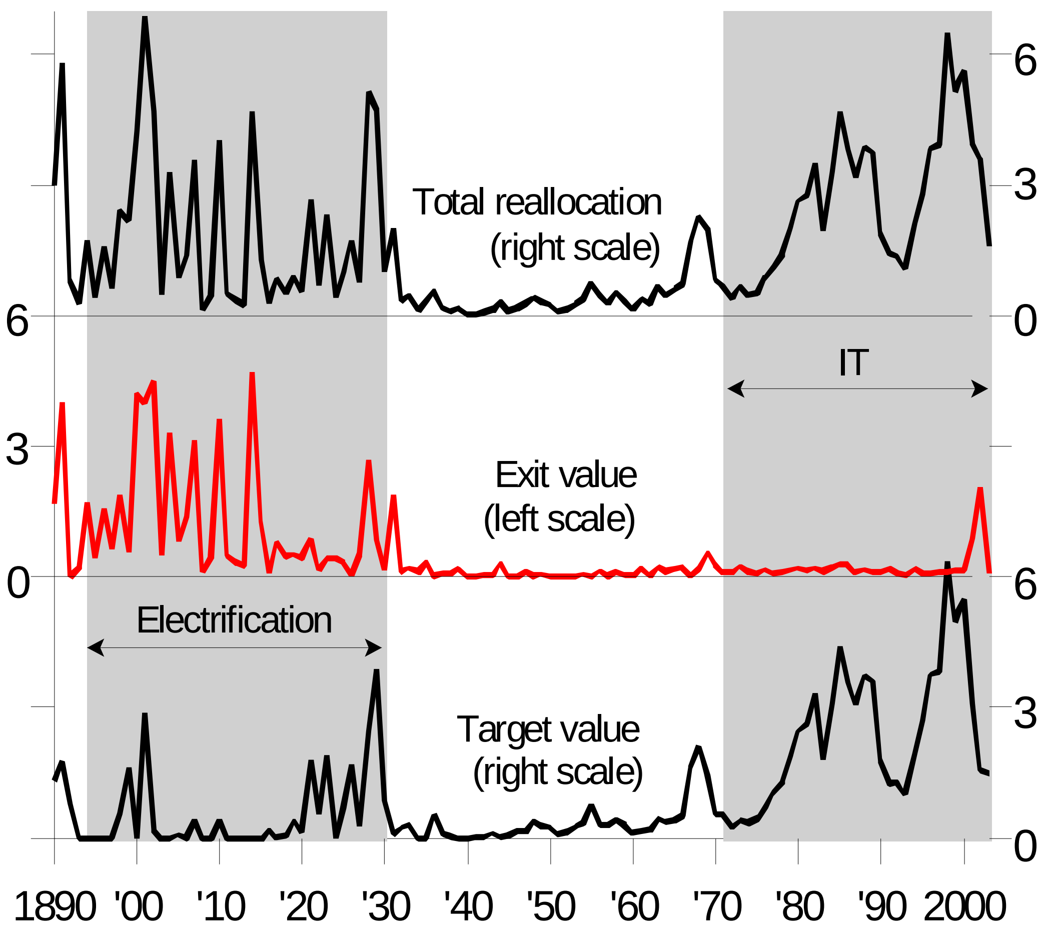


Figure 1. Reallocated capital and its components as percentages of stock market value, 1890-2003.

by the shaded areas, then the following patterns emerge:

(i) Mergers trend up and exits trend down over the century, but reallocation has no trend and is U shaped. The deviations from a linear trend are positively related with a correlation coefficient of 0.27, indicating that both margins respond to shocks.

(ii) Exits lead mergers during the electrification epoch, but not during the IT phase. Figure 2 shows the normalized time CDFs of exits and mergers during the two technological epochs. The second panel masks the fact – better seen in Figure 1 – that exits are dwarfed by mergers in the IT epoch. We shall argue later that this was because of the easing of bankruptcy laws that made mergers a more attractive reallocation mode.

Section 3 will show that merger waves simultaneously affect many sectors, suggesting that the origin of these waves was something aggregate, such as a GPT.

In the model, the arrival of a GPT raises the dispersion in Tobin's Q among existing and potential new firms. We then argue that of the five major merger waves normally identified for the 20th century (i.e., around 1900, the late 1920s, the late 1960s, the mid-1980s, and the late 1990s), all but the wave of the 1960s came about because of pressure to reallocate capital.

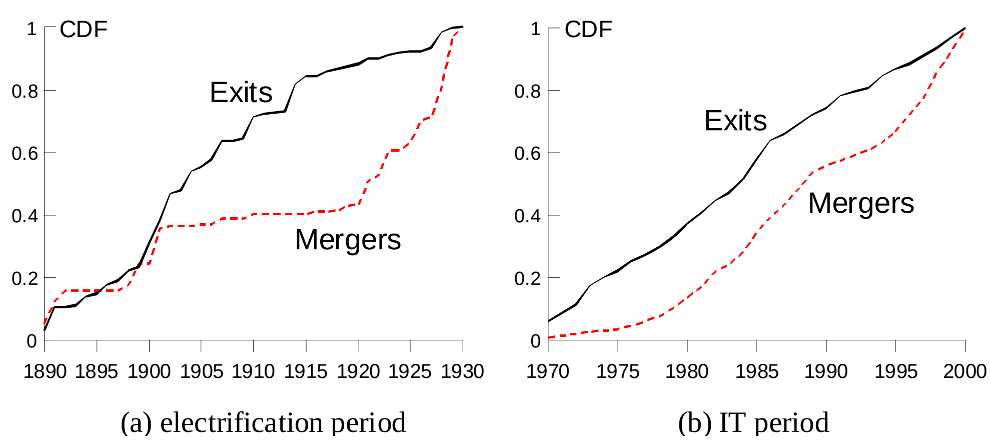


Figure 2. Normalized cumulative time distributions of exits and mergers in the two technological epochs.

Ours is one of the first attempts to introduce mergers into a macroeconomic model, and the first to target low-frequency variation. A recent general equilibrium treatment by Eisfeldt and Rampini (2006) uses an adjustment cost quite similar to ours, but they do not distinguish mergers from exit and re-entry as forms of reallocation and target high-frequency variation; Gowrisankaran and Holmes (2004) build an industry model in which a dominant firm faces a competitive, atomless fringe that it gradually buys out; Schoar (2002) surveys and provides evidence that mergers raise efficiency.

2 Model

The model is of an "Ak" type. At the outset there is just one production function in which capital is the only input. This is "old-vintage" capital. At date zero a better technology, a new GPT perhaps, appears and is not compatible with old-vintage capital. In the standard vintage-capital model, capacity to produce with the new technology must be created with new investment. To this we add two ways that old-vintage capital can be converted to new capital. The first is an exit and re-entry technology, and the second is a merger technology. The use of these two conversion technologies speeds up the growth of new capital and the diffusion of the GPT. Preferences are

$$\frac{1}{1-\sigma}\int_0^\infty e^{-\rho t} c_t^{1-\sigma} dt.$$

First we describe a standard one-technology "Ak" model that describes events before date zero.

One-technology model.—Aggregate output is

$$y = zk,$$

capital evolves as

$$\dot{k} = -\delta k + x, \tag{1}$$

and the income identity is

$$y = c + x.$$

Equating the marginal product of capital, z, to the user cost of capital, $r + \delta$, and substituting into the consumer's first-order conditions for optimal consumption $\dot{c}/c = (r - \rho)/\sigma$ gives us the constant-growth-rates of income and consumption

$$\frac{\dot{y}}{y} = \frac{\dot{c}}{c} = \frac{z - \delta - \rho}{\sigma}.$$

We shall also need this level property

$$\frac{x}{k} = \frac{\dot{k}}{k} + \delta = \frac{z - \delta(1 - \sigma) - \rho}{\sigma}. \tag{2}$$

The rate of interest is $r = z - \delta$. So far there are no transitional dynamics.

Two-technology model.—A new technology, z_2, appears at date zero. At the outset all capital then embodies the old technology z_1. How does the economy transit to a state in which all of its capital embodies technology z_2? For the intervening T periods, two kinds of capital coexist, k_1 and k_2. This is the era of reallocation. If the arrival of z_2 at $t = 0$ was unexpected, the growth rate before the transition would have been $(z_1 - \delta - \rho)/\sigma$, and after the transition is over at date T, say, the growth rate will be $(z_2 - \delta - \rho)/\sigma$.

While old capital, k_1, is still around, there are three ways to produce new capital. The first way is through the technology in (1) where a unit of c can be converted into a unit of either k_1 or k_2. This is the *de novo* investment technology. In addition, two other technologies are available. Both of them use k_1 and goods. We refer to these technologies as the *merger* and the *exit* technologies, and each is assumed to have constant returns to scale.

On the face of it, the two reorganization technologies look different: When a firm exits, its assets usually disperse and then reassemble in a collection of firms, some old, some new. By contrast, when a firm is acquired, its assets typically come under the control of one existing firm. Common to these situations, however, is that the disappearing firm is usually less efficient, and that its physical and especially human resources then move to where they are employed more efficiently.

Mergers.—Owners of k_2 buy capital from owners of k_1. The direct cost of converting a unit of k_1 into a unit of k_2 is s. As in Diamond (1982), we assume that s has the CDF $F(s)$ and density $f(s)$, and that a buyer meets different sellers in each period, but with a Poisson frequency normalized to unity and not alterable by spending effort. We follow Diamond and assume that the draw of s is i.i.d. in each meeting. Let mk_2 be the number of units acquired, so that m is the acquisition rate relative to k_2. The cheapest-to-convert units are acquired, so that if r is the costliest unit acquired,

$$m = F(r).$$

Total conversion costs are $\phi(m) k_2$, where

$$\phi(m) = \int_0^r s dF(s)$$

is the unit cost of adapting the acquired capital. Therefore $\phi(0) = 0$, $\phi' = r(m) > 0$ (because $dr/dm = 1/f$) and $\phi'' = 1/f > 0$. Thus ϕ is increasing and convex. For example,[1] if s is uniformly distributed on $[0, s^m]$,

$$\phi(m) = \left(\frac{s^m}{2}\right) m^2. \tag{3}$$

Exit.— The seller with k_1 units of inefficient capital faces the cost $s' \sim G(s')$ with density $g(s')$ of adapting his capital for sale. If all k_1 units are sold, total costs would be $k_1 \int_0^\infty s' dG(s')$. If he were to sell a fraction $\varepsilon < 1$ of the capital, he would sell the least-cost ones, i.e., those for which $s' \leq R(\varepsilon)$, where $R(\varepsilon)$ solves the equation

$$\varepsilon = G(R). \tag{4}$$

At this sell-off rate, the cost would be $\psi(\varepsilon) k_1$, where

$$\psi(\varepsilon) = \int_0^{R(\varepsilon)} s' dG(s') \tag{5}$$

is the unit cost. Differentiation of (5) and (4) shows that $\psi(0) = 0$, $\psi'(\varepsilon) = R(\varepsilon)$, and $\psi''(\varepsilon) = \frac{1}{g(R[\varepsilon])}$ so that ψ is increasing and convex. For example, if s' is uniformly distributed on $[0, s^\varepsilon]$, then (5) implies that

$$\psi(\varepsilon) = \left(\frac{s^\varepsilon}{2}\right) \varepsilon^2. \tag{6}$$

[1] $F(r) = \frac{r}{s^m}$, so that $r = s^m m$. Then $\int_0^r s dF(s) = \frac{1}{s^m} \int_0^r s ds = \frac{r^2}{2s^m}$. Thus $\phi(m) = \frac{r^2}{2s^m}$, i.e., (3).

Output and the evolution of k_1 and k_2.—Net of upgrading costs, output is

$$y = (z_1 - \psi[\varepsilon])\, k_1 + (z_2 - \phi[m])\, k_2, \tag{7}$$

consumption is

$$c = y - x_1 - x_2,$$

and the two capital stocks evolve as follows:

$$\dot{k}_1 = -\delta k_1 + x_1 - \varepsilon k_1 - m k_2, \tag{8}$$

$$\dot{k}_2 = -\delta k_2 + x_2 + \varepsilon k_1 + m k_2. \tag{9}$$

Equilibrium.—Equilibrium consists of paths for m, ε, x_1, x_2, and c such that firms maximize profits and the representative agent consumes optimally. The initial conditions are $k_{1,0} = 1$, $k_{2,0} = 0$, and the aggregate laws of motion (8) and (9) hold with the added restriction that $k_{1,t} \geq 0$. The model has neither external effects nor monopoly power and in Appendix B we use the planner's problem to derive the equilibrium formally. In this section we shall give the market-economy interpretation.

Upgrading.—Let q be the price of k_1, and Q the price of k_2. Optimal upgrading by z_1-firms and z_2-firms implies that

$$\psi'(\varepsilon) = \phi'(m) = Q - q. \tag{10}$$

In both cases the replacement cost for k_1 is q, and the upgraded capital has a price of Q. The difference between the two is equated, in (10), to the marginal cost of adjustment.[2]

Investment.—We assume that $x_2 > 0$. Then

$$Q = 1. \tag{11}$$

On the other hand, it will turn out that $q < 1$ for all $t \in [t, T)$, and therefore $x_1 = 0$ throughout the transition.

Output and upgrading rents.— k_1 and k_2 play a dual role here. Each produces output, and each assists in the upgrading process. Upgrading is subject to increasing marginal costs and so, in equilibrium, entails a rent. The per-unit upgrading rent that k_1 draws is

$$\pi^{\varepsilon}(q) \equiv \max_{\varepsilon} \left\{ \varepsilon - (q\varepsilon + \psi[\varepsilon]) \right\},$$

and the per-unit rent that k_2 draws is

$$\pi^{m}(q) \equiv \max_{m} \left\{ m - (qm + \phi[m]) \right\}.$$

Consumption growth during the transition is

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}\left(z_2 + \pi^m(q) - \rho - \delta\right) \tag{12}$$

and the rate of interest is

$$r = z_2 - \delta + \pi^m(q). \tag{13}$$

[2] In our partial-equilibrium treatment of takeovers (Jovanovic and Rousseau 2002), the equivalent of (10) is eq. (8). That paper also assumes adjustment costs on x that we have suppressed here to keep the analysis manageable.

Output in (7) rises monotonically because, by (10), ε and m both decline monotonically. This is driven by the monotonic rise in q.

The monotonic rise in q during the transition.—The model is solved as follows: To determine the endogenous variables ε, m, $\pi^{\varepsilon}(q)$, $\pi^{m}(q)$, $\dot{c}/c$, and r at some date, it is enough to know the value of q at that date. Therefore if we can solve for the time path of q, we shall have solved the model as a function of c_0 which we then obtain from the consumer's budget constraint.

The price of k_1 must be such that the marginal product of k_1 equals its user cost:

$$z_1 + \pi^{\varepsilon}(q) = (r + \delta) q - \dot{q}.$$

Since $\dot{Q} = 0$, the corresponding condition for k_2 is

$$z_2 + \pi^{m}(q) = r + \delta.$$

Combining these two conditions and eliminating r we are left with[3]

$$\frac{\dot{q}}{q} = z_2 + \pi^{m}(q) - \frac{(z_1 + \pi^{\varepsilon}[q])}{q}. \tag{14}$$

[3]Eq. (14) is derived for the planner's shadow price of k_1 in (24) of Appendix B. It also satisfies the usual arbitrage equation for asset prices: The annualized flow, rq, from selling a unit of k_1, must equal the instantaneous income plus capital gain less depreciation: $z_1 + \pi^{\varepsilon}(q) + \dot{q} - \delta q$, i.e.,

$$r_t q_t = z_1 + \pi^{\varepsilon}(q) + \dot{q}_t - \delta q_t.$$

When this equation holds, the owner of k_1 is indifferent between selling it on the takeover market and keeping it in operation for another period. Using (13) leads to (14).

Let q^* be the largest value of q at which

$$z_2 + \pi^m(q) = \frac{(z_1 + \pi^\varepsilon[q])}{q}. \tag{15}$$

Since $\pi^m(q) = \pi^\varepsilon(q) = 0$ when $q \geq 1$, we have $0 < q^* < 1$. Moreover,

$$q > q^* \implies \dot{q} > 0.$$

As long as $k_1 > 0$ we must have $q < 1$, otherwise k_1 and k_2 would sell at the same price which would be irrational for buyers. But q must approach unity as $t \to T$ because as of date T, $k_{1,t}$ becomes zero and ε_t and m_t must both become zero. That is, since $\phi'(0) = 0$, a unit of k_1 is at date T as valuable as a unit of k_2 because it can be upgraded costlessly. It must therefore be that

$$q_0 \in (q^*, 1) \text{ and } q_T = 1$$

and, from (14), that $\dot{q} > 0$ throughout the transition. Finally, $\dot{q}_T = z_2 - z_1$.

2.1 Summary of the transitional dynamics

The model's qualitative implications are as follows:

(i) *Output.*—At $t = 0$, output falls from $z_1 k_1$ to $(z_1 - \psi[\varepsilon_0]) k_1$ and then rises monotonically.

(ii) *The stock-price index.*—The value of capital also falls from 1 to q_0. Wealth falls from $k_{1,0}$ to $q_0 k_{1,0}$. Thereafter, q_t rises monotonically to 1, and k_1 falls monotonically to zero at date T, as do ε and m.

(*iii*) *Acquisitions.*—The value of acquisitions, qmk_2, is a continuous function which starts and ends at zero. Thus it must roughly have an inverted U pattern during the transition.

(*iv*) *Exits.*—The value of exits, $e = q\varepsilon k_1$, initially jumps and then declines monotonically. More precisely, Appendix B shows that if $\pi^m(q) = \pi^\varepsilon(q)$ for all q, then[4]

$$z_2 - z_1 \leq \delta \qquad \Longrightarrow \qquad \dot{e} < 0. \tag{16}$$

(*v*) *The rate of interest.*—It jumps up from $z_1 - \delta$ to $z_2 - \delta + \pi^m(q_0)$ at date zero and then declines monotonically to $z_2 - \delta$ where it remains thereafter.

(*vi*) *Consumption.*—Consumption growth declines monotonically after date zero. More precisely,

$$g_{c,t} = \begin{cases} \frac{z_1 - \delta - \rho}{\sigma} & \text{for } t < 0 \\ \frac{z_2 + \pi^m(q_t) - \delta - \rho}{\sigma} & \text{for } t \in (0, T) \\ \frac{z_2 - \delta - \rho}{\sigma} & \text{for } t \geq T. \end{cases} \tag{17}$$

Consumption falls at date zero (except perhaps when σ is large) and then gradually rises. Let $c_0^{(-)}$ denote consumption just before the shock, and c_0 consumption just

[4]More generally, the condition is $z_2 - z_1 + \max_q(\pi^m[q] - \pi^\varepsilon[q]) \leq \delta \Longrightarrow \dot{e} < 0$. Under (3) and (6), (10) and (11) imply that $\phi(m) = \frac{(1-q)^2}{2s^m}$ and $\psi(m) = \frac{(1-q)^2}{2s^m}$ so that

$$\pi^m(q) - \frac{1}{q}\pi^\varepsilon(q) \leq \frac{(1-q)^2}{2}\left(\frac{1}{s^m} - \frac{1}{s^\varepsilon}\right) \leq \frac{1}{8}\left|\frac{1}{s^m} - \frac{1}{s^\varepsilon}\right|.$$

In our simulation, the RHS is 0.01, and condition (16) is met.

after it. Appendix B shows that

$$\frac{c_0}{c_0^{(-)}} \lesseqqgtr q_0 \quad \text{as } \sigma \lesseqqgtr 1. \tag{18}$$

(*vii*) *Investment.*— $x_1 = 0$ throughout, $x_2 > 0$ and using (2)

$$\lim_{t \to T} \left(\frac{x_{2,t}}{k_{2,t}} \right) = \frac{z_2 - \delta (1 - \sigma) - \rho}{\sigma}. \tag{19}$$

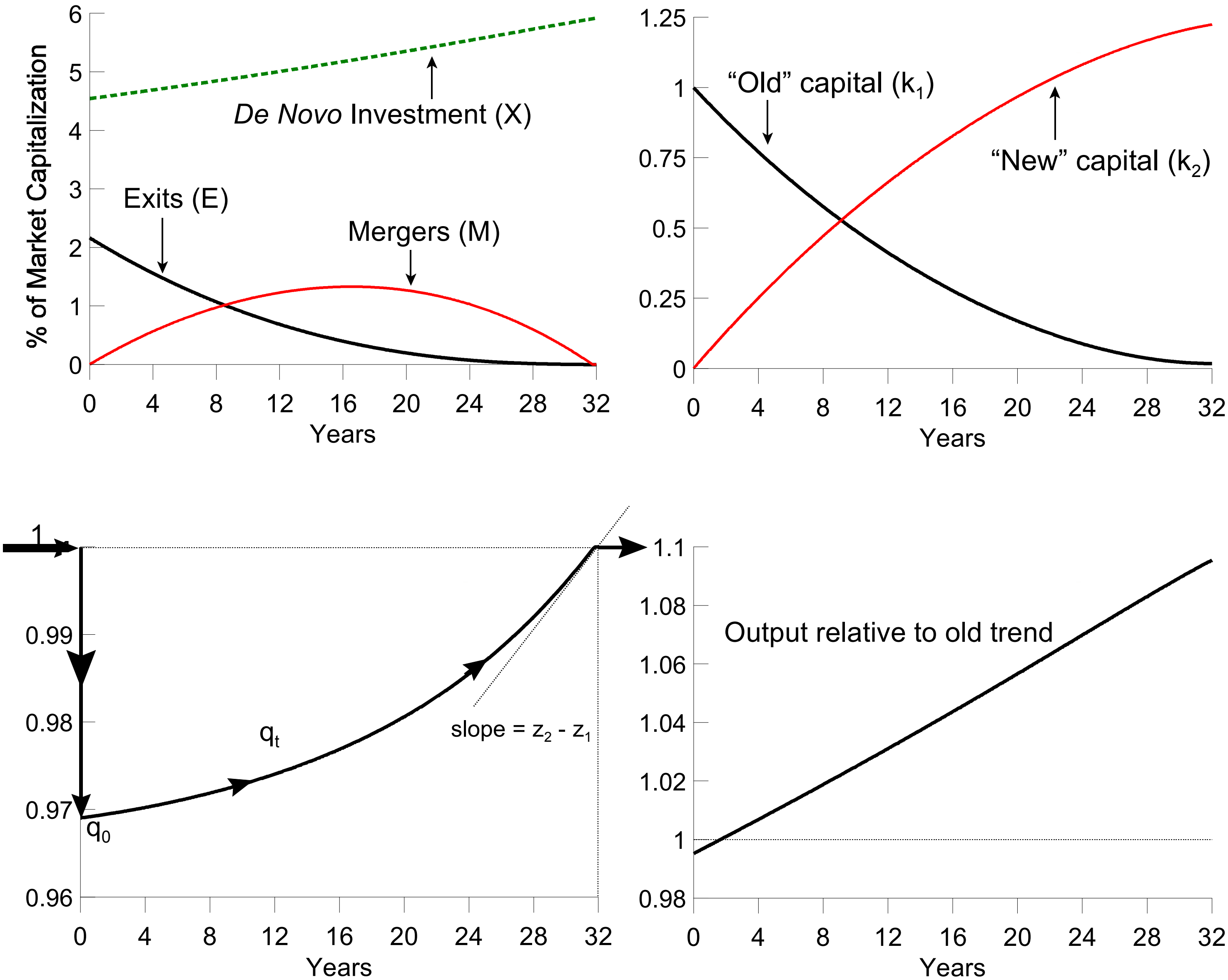
These properties all hold in the upcoming simulated example.

Simulation.—To illustrate how the model works, assume that $\rho = 0.025$, $\sigma = 1$ and $\delta = 0.04$ so that (16) is met. Let $z_1 = 0.07$ and $z_2 = 0.0725$, so that long-run growth, $z - \rho - \delta$, rises from 0.005 to 0.0075 per year. Let ϕ be as in (3) with $s^m = 1.28$ and ψ be as in (6) with $s^\varepsilon = 1.43$, in which case (15) has a unique solution $q^* = 0.94$ on the unit interval. The three date-0 boundary conditions are $k_1 = 1$, $k_2 = 0$, and the budget constraint,

$$q_0 = \int_0^T \exp\left(- \int_0^t r_\tau d\tau \right) c_t dt + \exp\left(- \int_0^T r_\tau d\tau \right) \frac{c_T}{\rho},$$

with r given in (13). The three date-T conditions are $k_{1,T} = 0$, $q_T = 1$, and (19).

Panel 1 of Figure 3 plots the three forms of investment in k_2 relative to market capitalization, $k_2 + qk_1$, namely acquisitions, $M = \frac{qmk_2}{k_2 + qk_1}$, exits $E = \frac{q\varepsilon k_1}{k_2 + qk_1}$, and *de novo* investment $X = \frac{x_2}{k_2 + qk_1}$ which is strictly positive throughout, as claimed in the Appendix after the proof of the planner's problem. Exits indeed lead mergers as indicated in Figure 2. Panel 2 shows the evolution of the capital stocks – it takes 32 years for k_1 to disappear. Panel 3 shows the sudden fall of q at $t = 0$ and its



Model settings:
$z_1 = 0.07$, $z_2 = 0.0725$, $s^{\varepsilon} = 1.43$, $s^m = 1.28$, $\rho = 0.025$, $\sigma = 1$, $\delta = 0.04$.

Figure 3. Transitional Dynamics.

subsequent recovery. Panel 4 shows the path of output during the transition relative to what it would have been in the absence of the productivity shock: Reallocation through exits and mergers reduces output in the short run.

3 Evidence

In this section we report evidence of a more general nature.

Acquisitions, exits and IPOs by sector If m and ε perform the same sort of reallocative function, then they should be positively correlated over sectors. It turns out that they are. The rank correlations between exits and initial public offerings (IPOs) on the one hand and acquisitions on the other are given below, with ranks based on the percentage of each type of reallocation in total sector value. The 15 manufacturing sector categories for the 1925-30 period are the ones used in David (1991).[5] For IT, we use the 62 sectors covered in the detailed fixed asset tables of the Bureau of Economic Analysis (2002). We include the rank correlations between mergers and IPOs because much of the exiting capital in the U.S. economy is likely to wind up back on the stock market through new security issues. Both sets of correlations fit the model well, and all three forms of reallocation are highly correlated

[5] The 15 sectors are chemicals, electrical machinery, food and tobacco, industrial machinery, leather and leather products, lumber and wood products, metals, motor vehicles and transport equipment, non-metal minerals excluding fuels, paper, printing and publishing, petroleum and coal, rubber, textiles, and stone, clay, and glass.

across sectors.

Period	rank correlation	significance	# of sectors
	Mergers and IPOs		
1925-1930	0.718	1%	15
1997-2000	0.480	1%	62
	Mergers and Exits		
1925-1930	0.343	10%	15
1997-2000	0.847	1%	62

Acquisitions and sectoral exposure to GPTs If 1890-1930 and 1970-2000 are indeed periods of rapid GPT diffusion, then we should have also seen more upgrading and reallocation in sectors that were absorbing more of the two GPT's. To examine this implication, we run a "value-weighted" least squares regression of target values as percentages of market value in their respective sectors on a measure of sectoral absorption of the two GPTs at the tail end of each epoch. For Electrification, this measure is the ratio of the share of sectoral horsepower that was electrified in 1929 to the share that was electrified in 1919. These data are from David (1991). For IT, the absorption measure is the ratio of the share of IT capital (equipment and software) in each sector's capital stock in 2000 to the share in 1990, and the data are from the detailed fixed asset tables of the Bureau of Economic Analysis (2002). The acquisitions that we report are for 1925-30 and 1997-2000.[6] That is, we look at the growth of the GPT shares over 10-year periods and then report acquisitions during the merger wave that occurred at the end of each period. The value-weighted least squares regression is simply generalized least squares with each moment condition weighted by the corresponding sector's share in total GPT capital.[7]

Figure 4 shows the regression results, with the areas of the circles proportional to the weighting factors. The two panels of the figure are comparable, and are constrained by the sectoral investment data that we could find for the electrification period. The relation is positive in both epochs, but more so for electrification.

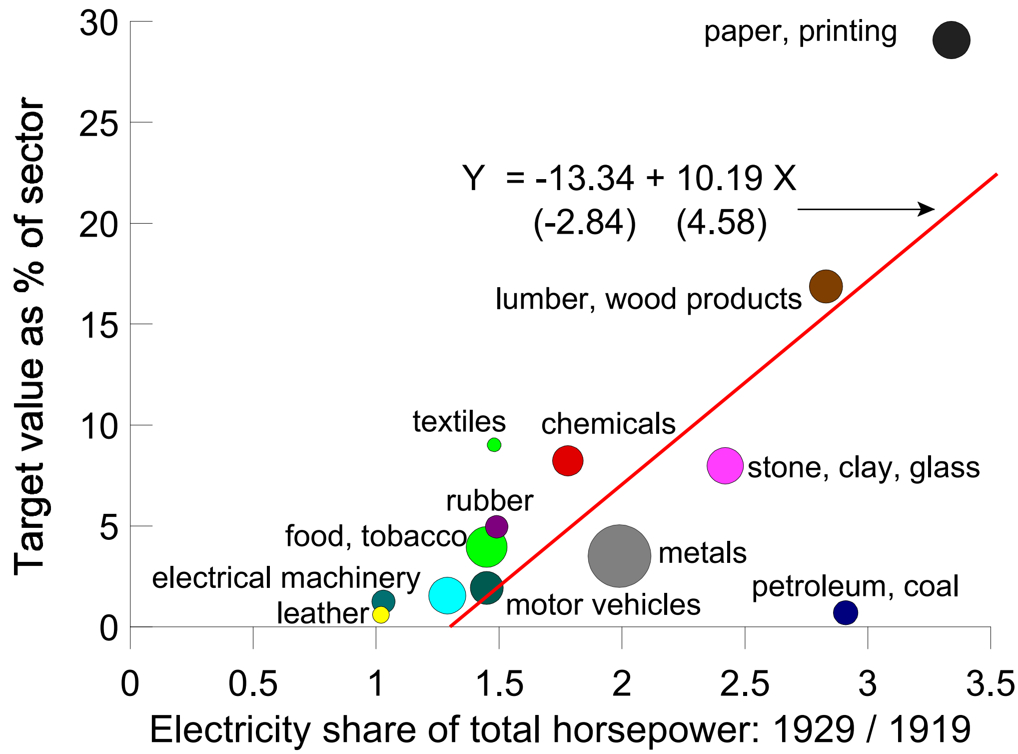
We also ran the regression with standard (i.e., unweighted) OLS. For the electrification period, the results were

$$M = \underset{(2.9)}{4.801} + \underset{(1.9)}{1.371}\ Share_{1929/1919} \quad N = 14,\ R^2 = .50,$$

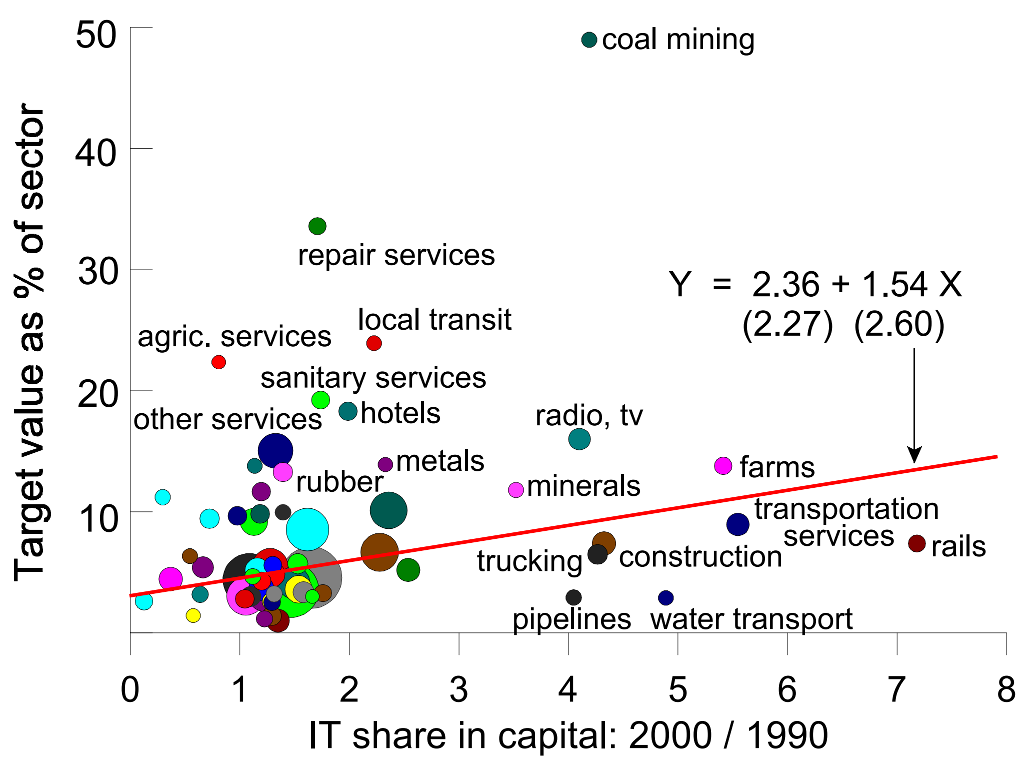
with t-statistics in parentheses. For the IT era, the estimates were

[6] A good deal of U.S. merger activity took place outside of the stock exchange over the 1890-1930 period, and a sectoral breakdown would not be possible unless we use these off-exchange transactions. Panel (a) of Figure 4 therefore uses all targets and sector designations recorded in the worksheets underlying Nelson (1959), and then divides by the total value of exchange-listed firms belonging to a given sector to form the vertical axis quantities. Panel (b) of Figure 4 reflects activity among exchange-listed firms only.

[7] In other words, for Electrification, we weight the observations by the share of total electrical horsepower that resides in each sector, whereas for the IT epoch we weight by the share of IT-capital (computer equipment and software) in each sector.



(a) electricity period



(b) IT period

Figure 4. Target values vs. changes in GPT shares over 10-year periods by sector.

$$M = \underset{(-1.6)}{-7.449} + \underset{(3.3)}{7.592}\ Share_{2000/1990} \quad N = 62,\ R^2 = .06,$$

which are weaker but qualitatively similar to our findings with value-weighted least squares.

The ages of targets and acquirers Technological transfer flows from firms that own k_2 to firms that own k_1. Since k_1 is older, we may expect that targets should be older than acquirers. Figure 5 plots the time series of the age of the targets minus the age of the acquirers, weighting each acquirer and target by their market capitalization at the end of the year before the merger before computing the average for each year. Age is defined as time elapsed since exchange listing. Some early years have no mergers with listed firms born after 1886 associated with them; we interpolated between years when needed, and then smoothed over all years. The model says that this number should be positive during the two reallocation episodes, and while the evidence does not confirm this resoundingly, the plot does show the predicted U shape.[8]

Trends in mergers and exits, the stock market drop, etc. Now to some evidence that the model does not match so well. First, the model does not explain the secular decline of exits and the rise of mergers, and in the next section we discuss

[8] The tendency for acquirers to become younger during the two GPT episodes is consistent with our finding that the age of IPO-ing firms was dramatically lower during these episodes than it was in the middle of the century (Jovanovic and Rousseau, 2001) .

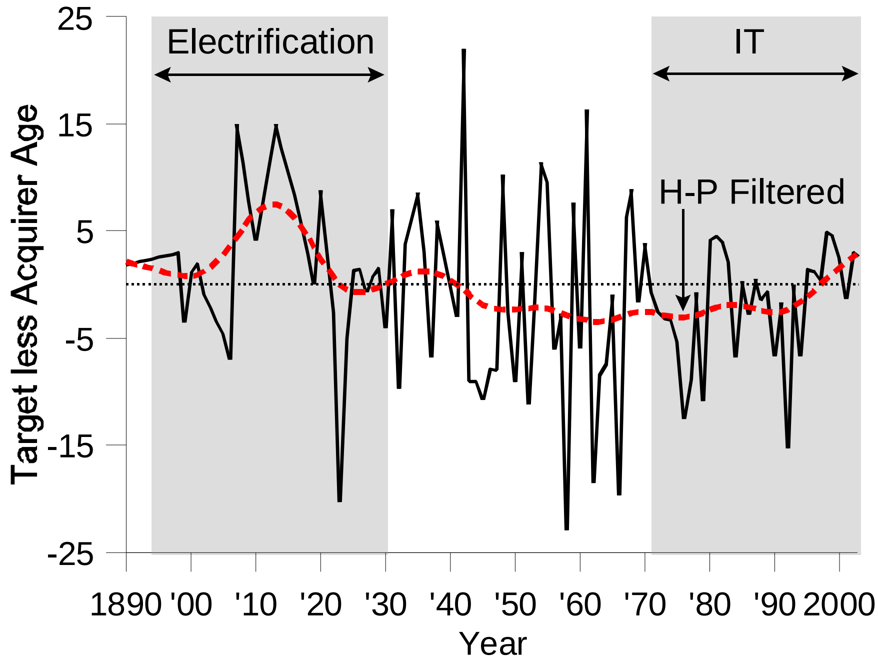


Figure 5: Average ages of targets less acquirers, 1890-2003.

changes in bankruptcy laws as one possible explanation for the shift. Second, since at $t = 0$ stock-market capitalization is q_0, the stock-market is supposed to decline at the outset of each GPT episode, though only by 3.1 percent for the simulation in Figure 3. The dramatic stock-price fall of 1973-4 confirms this implication, but no such decline occurred at the start of the electrification episode. Finally, the implication that $Q = 1$ contradicts the tendency for Q to often exceed 1 in the data. To fix this we put in adjustment costs for *de novo* investment; this complicated the algebra but left intact the implication that the GPT raises dispersion of q. Measured as the ratio of the average market-to-book values of target and exiting firms to the average market-to-book value of acquirers, during the IT era q/Q first fell and then rose, roughly as Panel 3 of Figure 3 depicts.

4 Other explanations

Two sets of institutional changes may contribute a part of the explanation for the phenomena that Figure 1 portrays: Changes in antitrust policy and changes in bankruptcy laws. We now discuss each in turn.

Changes in antitrust policy Shifts in antitrust stance might explain the ebb and flow of merger activity. Antitrust activism begins with the Sherman Act of 1890 which declared illegal every contract, combination (in the form of trust or otherwise) or conspiracy in restraint of interstate and foreign trade. The Clayton Act of 1914 made clear that horizontal mergers that substantially reduced competition fell into this category. Stigler (1966) argues, however, that neither these Acts nor the formation of the FTC in 1914 had much effect in reducing industry concentration until the courts began enforcing them more vigorously in the 1940's. Rather, Stigler argues that a strong barrier to horizontal mergers was not erected until 1950 when Congress closed a loophole in section 7 of the Clayton Act. Until then a firm could buy the assets of a potential target directly rather than merging with it, thereby escaping regulatory scrutiny. After 1950 antitrust activity declined steadily. Figure 6 reflects these inverted U shaped trends, where antitrust stance is proxied by the number of cases initiated by the Department of Justice per trillion constant-1998 dollars of

GDP.[9] The figure also marks a few milestones in antitrust history.[10] While the ratio of target capital to GDP is U shaped and trends up, the DOJ series is *inverted* U and trends *down*. At low frequencies, then, antitrust stance is negatively correlated with merger intensity.

On the other hand, the negative relation between the two series need not be causal. Instead, mergers and antitrust policy may both respond to

(i) *Technology.*—When a GPTs arrives, the need to reallocate assets becomes greater whereas, as in mid-century, when technology is more static, the government

[9] The number of antitrust cases is from Posner (1970, Table 1, p. 366) for 1890-1954, and from worksheets underlying Ghosal and Gallo (2001, Figure 1, p. 36) for 1955-94. We note two reservations about how well the number of cases can capture antitrust stance: First, (i) The DOJ can deter by means of threats instead of actions, or (ii) the merger may be approved after important divestitures. Both of these imply a high level of antitrust activism, but are not captured by the court-case data. Second, while DOJ and FTC antitrust activity has tapered off, private antitrust suits have increased dramatically over the years.

[10] The Sherman Act was rarely enforced by the courts until 1904, when the dissolution of the Northern Securities Company marked the start of a less tolerant stance towards trusts that was reaffirmed with the dissolution of the Standard Oil trust in 1911. The refusal of the courts to dissolve the U.S. Steel Trust in 1920 marked a swing in the pendulum towards a more lenient stance, which persisted until 1936 and the passage of the Robinson-Patman "anti-chain store" Act. The case of the Brown Shoe Company in 1962, occuring in the wake of the 1950 Act, is one in which a merger was disallowed that would have secured only 6 percent of the footwear industry for the acquirer.

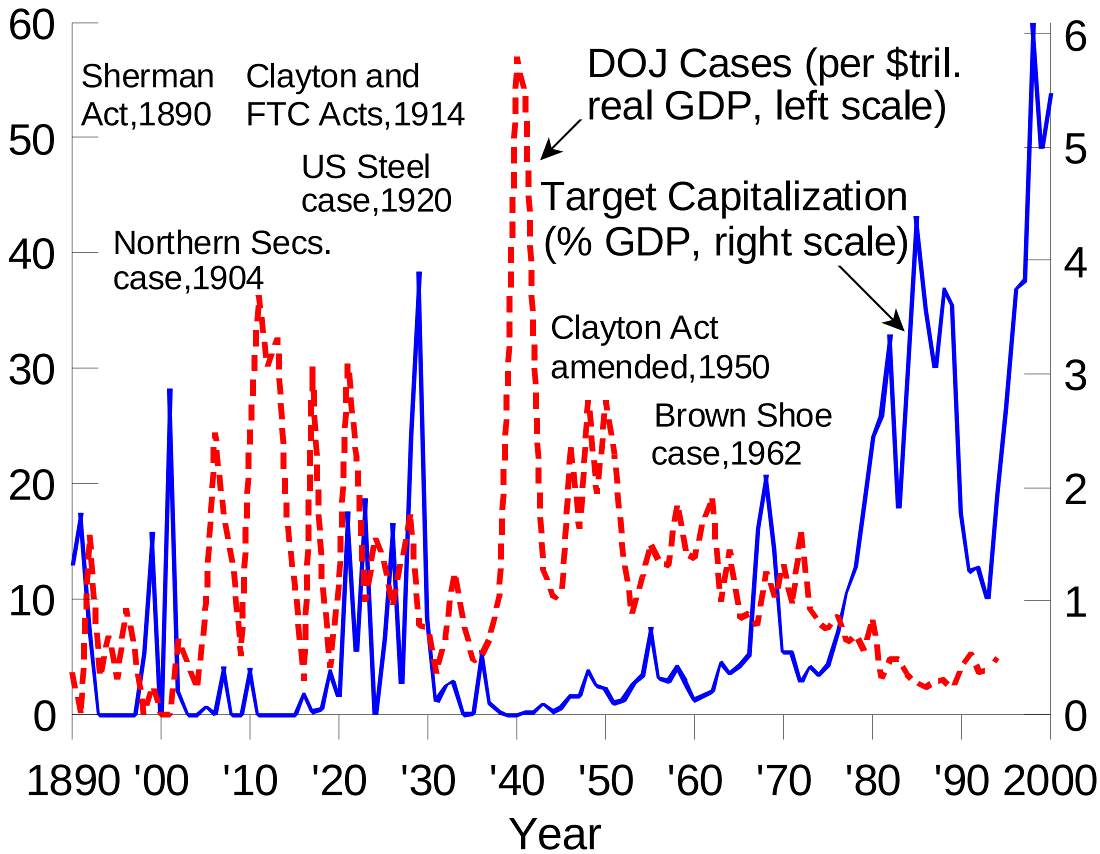


Figure 6: Antitrust stance and merger activity, 1890-2000.

worries more about monopoly. This is would be in line with the arguments in our paper.

(*ii*) *Openness.*—In the last century openness is U-shaped and trends slightly up: The shaded areas in Figure 1 coincide with times when the United States was more open to trade; from 1931-70, U.S. imports averaged only seven percent of GDP; whereas it was twice that in the Electrification era, and more than twice that in the last thirty years (Bergoeing and Kehoe 2001, Figure 4). When markets are global, there's less reason to worry about monopoly.

Since the GPTs arrived during times when the U.S. economy was relatively open, technology and openness are strongly positively correlated at low frequencies, and it is hard to identify which may have influenced antitrust policy more.

Changes in bankruptcy laws Managers of distressed firms now have more time to remain listed and seek suitable acquirers and hence, arguably, we see a rise in the merger-exit ratio after 1978. The history of bankruptcy laws in the U.S. is briefly this: Under the Bankruptcy Act of 1898, corporate bankruptcies fell under either of two common law forms of reorganization: 1) equity receivership, and 2) composition. In the first, major creditors would, often with the consent of the debtor, purchase its assets using a newly formed corporation and enforce their claims through a court-appointed receiver. In the second, all creditors would agree to a reorganization of the debtor's capital structure. Since it was difficult to get all creditors to agree to the terms of a reorganization, composition was designed for small, closely-held firms rather than public corporations. Inefficiencies in using these common law forms led to their replacement in 1938 by Chapters X and XI, respectively, of the Chandler Act. Under Chapter X, the Securities and Exchange Commission (SEC) would oversee the reorganization plans and the identification of a receiver. Lengthy litigation often ensued to establish which Chapter was appropriate: Management preferred Chapter XI because it kept them in control of assets while forgoing SEC oversight, but a substantial fraction of cases ended up in receivership under Chapter X (Posner 1997, pp.63-66) and would result in an "exit".

The laws eased in 1978 and probably led mergers to rise at the expense of exits. The Bankruptcy Reform Act of 1978 collapsed Chapters X and XI into the current Chapter 11 under which a debtor need not be insolvent to declare bankruptcy and which favors retention of management throughout the reorganization process. Bradley and Rosenzweig (1992) find that the two-year survival rate of failing firms between 1964 and 1989 rose from 74.5 percent in the years before the 1978 Act to 83.3 percent in the post-Act period, and that the probability of becoming delisted before a bankruptcy filing was three times greater in the pre-Act period.

In sum, the easing of bankruptcy laws probably explains the shift away from exits and towards mergers that we see when we compare the IT era with Electrification. The rise in total reallocation, however, we would ascribe to technology.

5 Conclusion

This paper argued that one role of mergers is to reallocate of assets towards an economy's more efficient firms, and that major technological change should lead to merger waves. We built a macroeconomic model in which merger waves do arise in response to a new GPT. During the two GPT epochs – electricity/internal combustion and IT, the model's main positive implications – that the dispersion of Q's, exits and mergers should all rise after a shock, and that exits should lead mergers – are borne out by the data, though other things remain unexplained.

We have studied the effects of a one-time, favorable shock to the efficiency of new capital, and not a Hicks-neutral shock to the aggregate production function that improves all factors. The next step in this aggregative line of thinking would be to study the effects of repeated shocks of this type, which would lead to a better understanding of how mergers interact with the business cycle.

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6 Appendix A

This Appendix describes the data sources and methods used to construct the time series illustrated in Figure 1.

Exit value— Exits for 1926-2003 are identified as firms that delist from the stock files distributed by the University of Chicago's Center for Research in Securities Prices (CRSP). This can occur due to liquidation, bankruptcy, financial distress, or lack of investor interest. Before assigning a firm as an "exit," we check the list of hostile takeovers from Schwert (2000) for 1975-1996 and individual issues of the *Wall Street Journal* for 1997-2003 to ensure that we record firms taken private under hostile tender offers as mergers. For 1885-1925, we identify exits as firms that are dropped from the end-of-year price and return listings for New York Stock Exchange (NYSE) firms as published in *The Commercial and Financial Chronicle*, *The New York Times*, and *The Annalist*.

Target value— Targets for 1926-2003 are the 9,758 firms that are coded in CRSP as having exited due to merger. For 1895-1930 we use the original worksheets for mergers in the manufacturing and mining sectors that underlie Nelson (1959), and for 1890-1894 we use the financial news section of weekly issues of the *Commercial and Financial Chronicle.* The target series uses the market values of exchange-listed firms at the end of the year that immediately precedes their acquisition.

Stock market value— The stock market capitalizations used to form all of the percentages shown in Figure 1 are from CRSP for 1925-2003 and our backward extension for earlier years. For the pre-1925 period, prices and par values are from the *The Commercial and Financial Chronicle,* and book capitalizations are from various issues of *Bradstreet's*, *The New York Times*, and *The Annalist.* Coverage for the NYSE begins in 1890, the AMEX in 1962, and NASDAQ in 1972.

7 Appendix B

This Appendix presents the planner's solution that the equilibrium described in section 2 decentralizes, and provides proofs of the claims in (16) and (18).

7.1 The planner's solution

The economy is convex, competitive and there are no external effects. We derive the optimal solution for the planner here, whereas in the text we reinterpret the optimum in terms of prices. We shall use optimal control. Substitute c from the utility function using (7) and the income identity. Then the Hamiltonian is

$$H = e^{-\rho t} \left\{ \begin{array}{c} U\left[(z_1 - \psi[\varepsilon])\,k_1 + (z_2 - \phi[m])\,k_2 - x_2\right] + q^*\left(-[\delta+\varepsilon]\,k_1 - mk_2\right) \\ +Q^*\left([m-\delta]\,k_2 + \varepsilon k_1 + x_2\right) + \lambda^* k_1 \end{array} \right\}$$

where $e^{-\rho t}q^*$ is the multiplier on the $\dot{k}_1$ constraint, $e^{-\rho t}Q^*$ is the multiplier on the $\dot{k}_2$ constraint, and $e^{-\rho t}\lambda^*$ is the multiplier on the non-negativity of k_1. To save on notation, we have assumed that $x_1 = 0$. This is valid if $Q^* > q^*$ so that the planner values k_2 more than k_1. We also ignore the non-negativity constraint on x_2. The FOCs are

$$\frac{\partial H}{\partial m} = 0 = -U'(c)\,\phi'(m) + Q^* - q^* \tag{20}$$

$$\frac{\partial H}{\partial \varepsilon} = 0 = -U'(c)\,\psi'(\varepsilon) + Q^* - q^* \tag{21}$$

$$\frac{\partial H}{\partial x_2} = 0 = -U'(c) + Q^*$$

$$-\rho q^* + \dot{q}^* = -\frac{\partial H}{\partial k_1} = -U'(c)\,(z_1 - \psi[\varepsilon]) + (\delta+\varepsilon)\,q^* - \varepsilon Q^* + \lambda^*$$

$$-\rho Q^* + \dot{Q}^* = -\frac{\partial H}{\partial k_2} = -U'(c)\,(z_2 - \phi[m]) + mq^* - (m-\delta)\,Q^*.$$

Now define

$$Q = \frac{Q^*}{U'(c)} \quad \text{and} \quad q = \frac{q^*}{U'(c)} \text{ and } \lambda = \frac{\lambda^*}{U'(c)}.$$

Then the equations become

$$\phi'(m) = Q - q,$$

$$\psi'(\varepsilon) = Q - q,$$

which is the same as (10),

$$Q = 1,$$

which is the same as (11),

$$\frac{-\rho q U' + \dot{q} U' + q \dot{U}'}{U'} = -(z_1 - \psi[\varepsilon]) + (\delta + \varepsilon) q - \varepsilon Q + \lambda$$

and

$$\frac{-\rho Q U' + \dot{Q} U' + Q \dot{U}'}{U'} = -(z_2 - \phi[m]) + mq - (m - \delta) Q,$$

because

$$-\rho q^* + \dot{q}^* = -\rho q U' + \dot{q} U' + q \dot{U}'$$

and

$$-\rho Q^* + \dot{Q}^* = -\rho Q U' + \dot{Q} U' + Q \dot{U}'.$$

Since $Q = 1$, and since $k_1 > 0$ on $[0, T]$, these conditions simplify to

$$\phi'(m) = 1 - q, \tag{22}$$

$$\psi'(\varepsilon) = 1 - q, \tag{23}$$

$$\frac{\dot{q} U' + q \dot{U}'}{U'} = -(z_1 - \psi[\varepsilon]) - \varepsilon(1 - q) + (\rho + \delta) q$$

and

$$\frac{\dot{U}'}{U'} = -(z_2 - \phi[m]) + m(1 - q) + \rho + \delta,$$

or,

$$\frac{\dot{q}}{q} + \frac{\dot{U}'}{U'} = -\frac{(z_1 + \pi^{\varepsilon}[q])}{q} + \rho + \delta$$
$$\frac{\dot{U}'}{U'} = -(z_2 + \pi^{m}[q]) + \rho + \delta.$$

in terms of the π^i defined in the text. This reduces to a single differential equation for q;

$$\frac{\dot{q}}{q} = z_2 + \pi^{m}[q] - \frac{(z_1 + \pi^{\varepsilon}[q])}{q}, \tag{24}$$

which is the same as (14). The only stationary solution would be a value q^* at which

$$(z_2 + \pi^{m}[q]) = \frac{(z_1 + \pi^{\varepsilon}[q])}{q} \tag{25}$$

for all $t \in [0, T]$.

Both sides of (25) are continuous functions of q. As $q \to 0$, the RHS is larger and at $q = 1$ $\pi^{\varepsilon} = \pi^{m} = 0$ so that the LHS is larger, and so at least one solution for q^* exists on the unit interval. If there are many, let

$$0 < q^* < 1,$$

denote the *largest* of them. Then q^* is unstable to the right in the sense that,

$$q > q^* \implies \frac{\dot{q}}{q} > 0,$$

and paths starting above q^* must converge to unity. Paths that start below q^* or at q^* can never exceed it. Therefore we must have

$$q_0 > q^*,$$

or else q_t could not converge to unity. But the latter is true in light of (22) and (23) and the assumption that $\phi'(0) = \psi'(0) = 0$.

A caveat: The planner's problem ignores the constraint $x_2 \geq 0$. If the upgrading technology ϕ or ψ is efficient enough, the planner may prefer to set not just x_1 (which we have set equal to zero) but also x_2 equal to zero for a while, so that Q too could fall below unity for a while. Our simulation generates a path for x_2 well above zero, so this is not a practical problem.

7.2 Proofs of (16) and (18)

Proof of (16).—Since $e = q\varepsilon k_1$,

$$\dot{e} \leq 0 \text{ iff } \frac{\dot{q}}{q} + \frac{\dot{\varepsilon}}{\varepsilon} \leq -\frac{\dot{k}_1}{k_1}.$$

But since $-\dot{k}_1 = \delta k_1 + \varepsilon k_1 - x_1 + mk_2$ and since $x_1 = 0$, $-\frac{\dot{k}_1}{k_1} \geq \delta + \varepsilon$. With (14) this implies that $\dot{e} \leq 0$ if

$$z_2 + \pi^m(q) - \frac{(z_1 + \pi^\varepsilon[q])}{q} + \frac{\dot{\varepsilon}}{\varepsilon} \leq \delta + \varepsilon.$$

Since $q \leq 1$ and $\dot{\varepsilon} \leq 0$, it suffices that

$$z_2 - z_1 \leq \delta + \varepsilon + \frac{\pi^\varepsilon(q)}{q} - \pi^m(q).$$

which implies (16).

Proof of (18).—Consider the consumer's budget constraint. We normalized $k_1(0) = 1$. All capital is of type 1 at date zero, and its price is 1. Then wealth $= 1$ just before the shock and $= q_0$ just after it. Just before the shock the constraint reads

$$1 = c_0^{(-)} \int_0^\infty e^{-(r-g_c)t} dt = c_0^{(-)} \int_0^\infty e^{-(\rho+(\sigma-1)g_c)t} dt,$$

where g_c is the first line of (17), and just after the shock it reads

$$q_0 = c_0 \int_0^\infty \exp\left(-\int_0^t \left(\rho + (\sigma-1)\, g_{c,\tau}\right) d\tau\right) dt,$$

where $g_{c,t}$ is composed of the second and third lines of (17). Now $q_t < 1$ as long as $k_1 > 0$, and so $\pi^m > 0$ and $g_{c,t} > g_c$ for all $t \geq 0$. Therefore

$$\frac{c_0}{c_0^{(-)}} = q_0 \frac{\int_0^\infty e^{-(\rho+(\sigma-1)g_c)t} dt}{\int_0^\infty \exp\left(-\int_0^t \left(\rho + (\sigma-1)\, g_{c,\tau}\right) d\tau\right) dt}$$

When $\sigma = 1$, $c_0 = q_0 c_0^{(-)}$. Since $g_{c,t} > g_c$ for all t, when $\sigma < 1$, $c_0 < q_0 c_0^{(-)}$, and the opposite for $\sigma > 1$, and (18) follows.