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 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. The model's main implication – that exits should lead mergers – is supported by data from both epochs.

1 Introduction

The Q-theory of investment implies that reallocation waves should occur at times when the dispersion in Q's among firms is high. Capital should flow from low-Q firms to high-Q firms. Here we formulate a theory of economy-wide merger waves as reallocation episodes prompted by the arrival of major technologies that raise the dispersion in Q among existing and potential new firms. Through the lens of our model, we study the 20th century and argue that of the five major merger waves, all but the wave of the 1960's came about because of pressure to reallocate capital, pressure that came from two bursts of general-purpose technologies – electricity and internal combustion, and information technology (IT).

When adopting a new technology, a firm may re-train some of its workers and replace others; it can re-fit its buildings and equipment, where possible, and replace the rest. If it fails in the attempt to reorganize internally, the firm will probably disappear and its assets will be reorganized *externally*. In that case the firm will either liquidate, or it will be taken over. Either way, however, the existing human and physical capital simply changes management. New technology spreads faster if such reallocation works smoothly. This paper studies these mechanisms.

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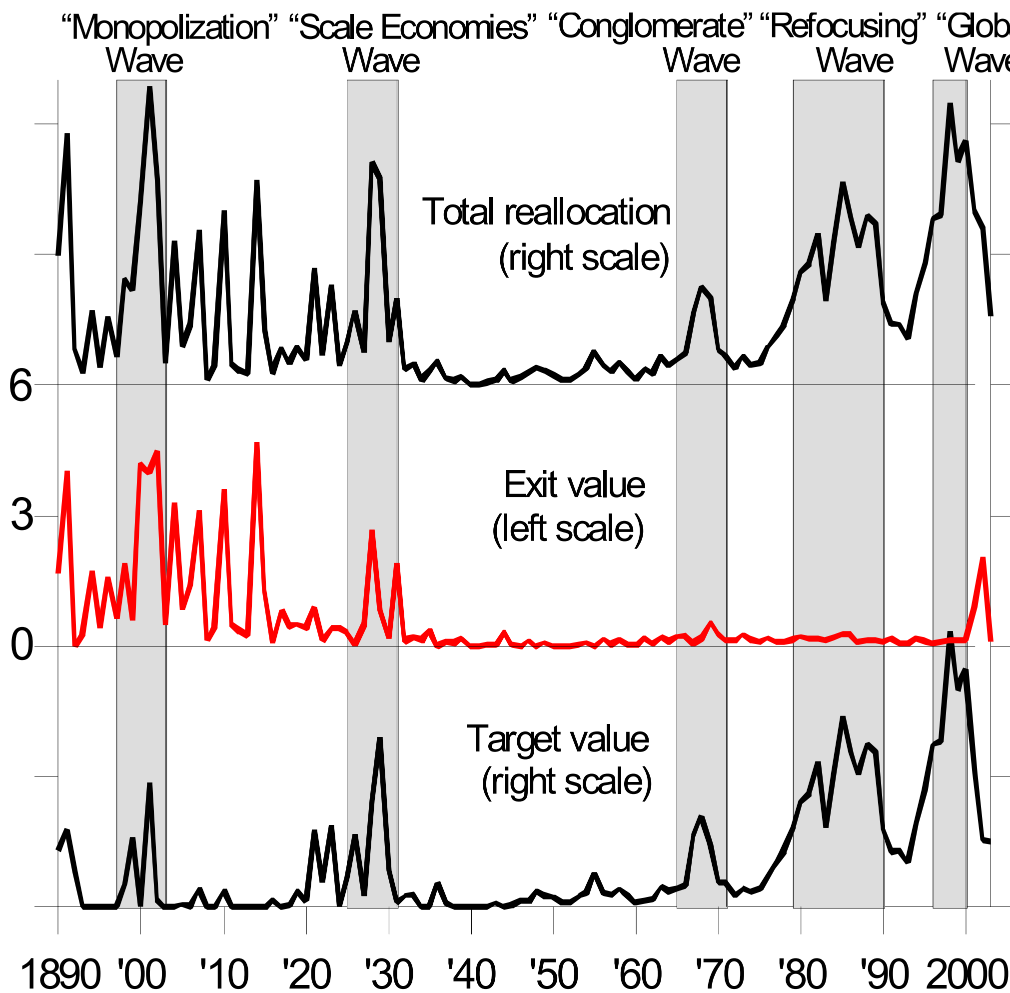


Figure 1: Reallocated capital and its components as percentages of stock market value, with merger waves shaded, 1890-2003.

In particular, we study and measure the two external adjustment mechanisms – mergers and exit – using the stock-market capitalization of the firms involved. In Figure 1, the U-shaped line in the upper panel 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 capitalization 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.[1] The line in the lower panel is the stock-market value of merger targets.[2]

The shaded areas represent the five merger waves that we have identified over the past century, and at the very top we list the names commonly given to these waves.[3] In light of our view that reallocation may have been prompted by the emergence of general purpose technologies (GPTs), three specific points emerge from Figure 1:

1. Each merger wave was accompanied by a rise in exits. The deviations from trend are positively related – the correlation is 0.27.

2. Exits lead mergers during the electrification epoch. Exits lead mergers in the IT epoch as well, but this is not obvious from Figure 1 because of the tremendous growth of mergers relative to exits.

3. While mergers have five waves and have grown relative to exits by a factor of more than 200 over the century, total reallocation has no significant trend, and is U shaped.[4]

Fact 1 suggests that society uses both margins to respond to shocks. Fact 2 guides the formulation of the model where, following a shock, it takes time for qualified acquirers to emerge. Fact 3 suggests that while the reallocation mode has shifted towards mergers, its total extent was roughly the same in the two epochs.

We use the model to estimate the value to the economy of having mergers as a mechanism of absorbing the new technology. Surprisingly, perhaps, we find that value

[1]Exits for 1926-2003 are defined as firms that leave the stock files distributed by the University of Chicago's Center for Research in Securities Prices (CRSP). Delisting from CRSP 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 disappearances from the New York Stock Exchange (NYSE) using contemporary newspapers. The stock market capitalizations used to form the ratios in Figure 1 are from CRSP for 1925-2003 and our backward extension of CRSP for earlier years. For the pre-1925 period, prices and par values are from the *The Commercial and Financial Chronicle,* which is also the source of firm-level data for the price indexes reported in the Cowles Commission's *Common Stock Prices Indexes* (1939), 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.

[2]We identify targets for 1926-2003 as 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 from Nelson (1959), and for 1890-1894 we use the financial news section of weekly issues of the *Commercial and Financial Chronicle.* The target series in Figure 1 includes the market values of exchange-listed firms in the year prior to their acquisition.

[3]We define merger "waves" as starting when the series for the value of target firms stays above a tightly-specified HP trend (λ=100 in the RATS filter program) for two or more consecutive years. The wave "ends" when the series falls below trend for two consecutive years.

[4]E.g., the ratio of the market values of merger targets to exiting firms averaged 0.1 from 1900-09, and 26.1 from 1990-99.

to be quite modest in terms of output even though the diffusion of new technology is much slower in the absence of a market for mergers.

Our contrast of two periods of major technological change – electrification (1890-1930) and IT (1970-2000) is in the spirit of David (1991). It would seem that four of the five merger waves in Figure 1 were a part of the needed reallocation that occurred during two technological transformations. The middle "conglomerate" wave, which is sometimes attributed to "managerial hubris," does not seem to fit our story.

2 Model

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. We then add a second technology with its own capital that suddenly and unexpectedly becomes available.

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

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

Thus far the model has 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 different ways to produce new capital. The first way is through the technology in (1) in which 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.

Mergers.—Owners of k_2 buy capital from owners of k_1. In this case the buyers face a cost c of converting k_1 into k_2. As in Diamond (1982), we assume that the cost has the CDF $F(c)$ and density $f(c)$. These costs are buyer-specific. 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 first, so that if r is the costliest unit acquired,

$$m = F(r).$$

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

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

is the unit cost of adapting the acquired capital. Therefore $\phi(0) = 0$, $\phi' = r(m) > 0$ (because $dr/dm = 1/f$) and $\phi'' = 1/f > 0$. Therefore ϕ is increasing and convex. For example, if c is uniformly distributed on $[0, c^m]$,[5]

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

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

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

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 c is uniformly distributed on $[0, c^\varepsilon]$, then (5) implies that

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

[5] $F(r) = \frac{r}{c_m}$, so that $r = c_m m$. Moreover, $\int_0^r c dF(c) = \frac{1}{c_m} \int_0^r c dc = \frac{r^2}{2c_m}$. Thus $\phi(m) = \frac{r^2}{2c_m}$, which leads to (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 m, ε, x_1, and x_2 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 the Appendix uses 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 implies that

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

and optimal upgrading by z_2-firms implies that

$$\phi'(m) = Q - q. \tag{11}$$

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) and (11), to the marginal cost of adjustment.[6]

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

$$Q = 1. \tag{12}$$

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

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

[6] In our partial-equilibrium treatment of takeovers as an investment (Jovanovic and Rousseau 2002), the equivalent of (11) is eq. (8). That paper also assumes adjustment costs on x which we have suppressed here in order to keep the analysis manageable.

and the per-unit rent that k_2 draws is

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

Consumption growth during the transition is

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}\left(z_2 + \pi^m(q) - \rho - \delta\right) \tag{13}$$

and the rate of interest is

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

Output in (7) rises monotonically because, by (10) and (11), ε and m both decline monotonically. This is driven by the monotonic rise in q that we are about to show.

The monotonic rise in q during the transition.—If we can solve for q, we shall be able to infer ε, m, $\pi^\varepsilon(q)$, $\pi^m(q)$, $\dot{c}/c$, and r. 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[7]

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

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

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

for all $t \in [0, T]$. Since $\pi^m(q) = \pi^\varepsilon(q) = 0$ when $q \geq 1$, we have $0 < q^* < 1$. This rest-point q^* is unstable from above:

$$q > q^* \quad \Longrightarrow \quad \dot{q} > 0.$$

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, $\dot{q}_T = z_2 - z_1$. Figure 2 illustrates the solution for q_t.

Summary of implications for the transition.—The qualitative implications are as follows:

[7] This equation is derived for the planner's shadow price of k_1 in (26) of the Appendix.

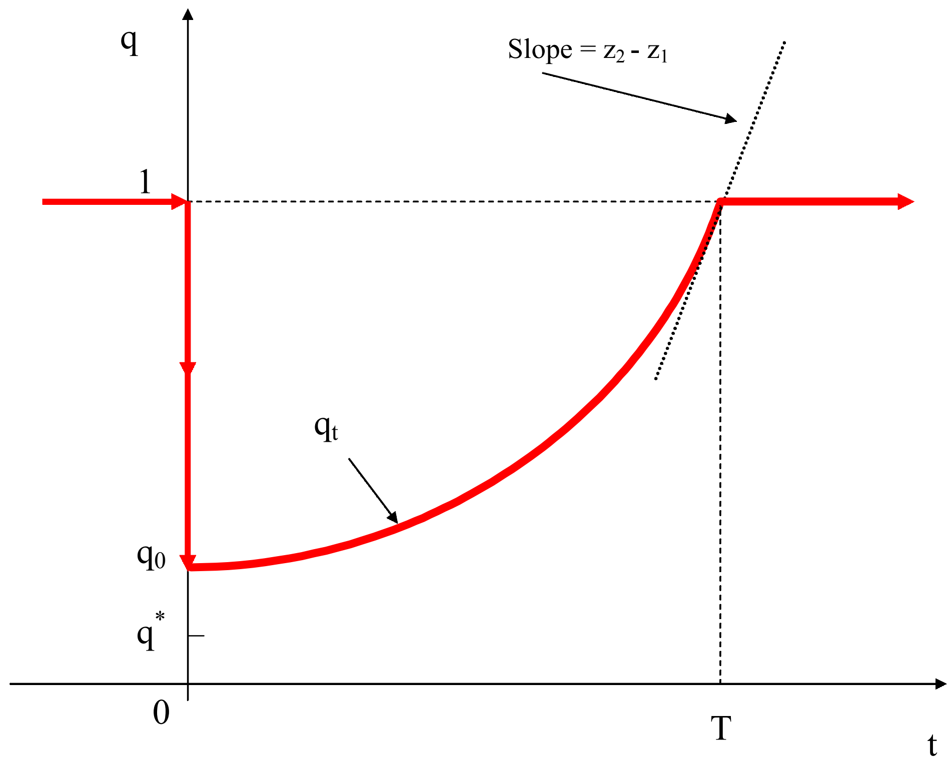


Figure 2: The solution for q_t.

1. At $t = 0$, output falls from $z_1 k_1$ to $(z_1 - \psi[\varepsilon_0])\, k_1$ and then starts to rise monotonically.

2. The value of capital also falls from 1 to q_0. Wealth falls from $k_{1,0}$ to $q_0 k_{1,0}$.

3. Thereafter, q_t rises monotonically to 1, and k_1 falls monotonically to zero at date T, as do ε and m.

4. Total exits, $q\varepsilon k_1$, decline monotonically, whereas total acquisitions, qmk_2, start and end at zero and are essentially inverted U-shaped during the transition.

5. The rate of interest jumps from $z_1 - \delta$ to $z_2 - \delta + \pi^m(q_0)$ and then declines monotonically to $z_2 - \delta$ where it remains thereafter.

6. Consumption falls at date zero. After that consumption growth declines monotonically. More precisely,

$$g_c = \begin{cases} \frac{z_1 - \delta - \rho}{\sigma} & \text{for } t < 0 \\ \frac{z_2 + \pi^m(q_t) - \delta - \rho}{\sigma} & \text{for } t \in (0, T) \\ \frac{z_2 - \delta - \rho}{\sigma} & \text{for } t \geq T. \end{cases} \tag{15}$$

7. Investment $x_1 = 0$ throughout, $x_2 > 0$ and using (2)

$$\lim_{t \to T} \left(\frac{x_{2,t}}{k_{2,t}} \right) = \frac{z_2 - \delta (1 - \sigma) - \rho}{\sigma}. \tag{16}$$

3 Simulations

3.1 Parameter choices

We now simulate the model. We assume that $\sigma = 1$ and that adjustment costs are quadratic as in (3) and (6). That is,

$$\phi (m) = \left(\frac{c^m}{2} \right) m^2 \quad \text{and} \quad \psi (\varepsilon) = \left(\frac{c^\varepsilon}{2} \right) \varepsilon^2. \tag{17}$$

We turn first to calibrating these adjustment costs.

3.1.1 Liquidation costs

Liquidation costs break down into three components. (*i*) Bankruptcy costs, (*ii*) Direct costs of disposing of the assets, and (*iii*) Indirect costs that arise because assets are partly specific to the liquidating firm.

(*i*) *Bankruptcy costs.*—Warner (1977) examines the direct costs of corporate bankruptcy for a sample of 11 railroads firms that were in bankruptcy proceedings between 1933 and 1955. Direct costs are fees charged by lawyers, accountants, consultants, and expert witnesses, and the value of the time that management diverts to oversee the proceedings (p. 338). The size of these costs as a percent of the total value of firm assets ranged from 1.7 percent to 9.1 percent at the time that the bankruptcies were declared and averaged 5.3 percent. For our purposes, however, 5.3 percent is too low for two reasons. First, bankruptcy involves indirect costs such as lost sales, lost profits (not included under the cost of management's time), and the inability of the trustee to run the firm efficiently while the firm is in bankruptcy proceedings. This would suggest that bankruptcy costs far exceed 5.3 percent. Second, a sample of railroads in the 20 years following the Great Depression is not representative of the mix of firms in the stock market, both then and now, and there appears to be a negative relation between bankruptcy costs and the size of the firm (Warner, p. 344). Since the railroads in Warner's study were among the largest firms in the stock market, if this result can be applied to other sectors, it is likely that bankruptcy costs would be substantially higher for the non-railroad firms that account for the majority of stock market value. A more reasonable estimate would be 10 percent.

(*ii*) *Direct costs of asset disposal.*—Himelstein (2002) cites evidence that the costs of selling the assets of technology firms through middlemen are currently about 7.5 percent of asset value, i.e., about the same as they are in the real-estate market.

(*iii*) *Firm-specificity of assets.*—Ramey and Shapiro (2003, Table 3) report a much higher liquidation cost of 60 percent in the defense industry, but this number also cannot be representative because the salvage market for defense-related equipment is probably thinner than that for other types of equipment.

If we take the loss of firm-specific value to be smaller than the Ramey and Shapiro estimate but equal to the sum of the other two components (10+7.5=17.5 percent), we end up with a liquidation cost of 35 percent. This is the value that we shall impose on the simulations. The details follow shortly.

3.1.2 Merger costs

We found few direct estimates of merger costs in the literature. But we would expect merger costs to be smaller than 35 percent of value because items (*ii*) and (*iii*) from the list of liquidation costs seem to have no counterpart in mergers, at least not if all assets are retained by the merged entity. On the other hand, item (*i*) does have a counterpart in that accountants and investment bankers are usually heavily involved in mergers.

Discussing merger activity during the "conglomerate" wave of the 1960's, Steiner (1975, p. 175) states that "as the roughest of estimates, the combination of brokerage fees, registration, advertising, mailings, and other out-of-pocket costs in routine acquisitions results in a cost of acquisitions of at least 3 percent of the market value of the shares acquired and more usually 4 or 5 percent."

Binder (1973) studies the same period and estimates that direct costs in contested mergers were at least twice as high as the costs of a routine uncontested one, and might be four times as much for a major contest. Since rough data from Steiner (p. 178) imply that perhaps 13 percent of mergers are contested, we compute a weighted average of the cost estimates of Steiner (5 percent) and Binder (10-20 percent) to arrive at a final estimate of about 6.3 percent (i.e., (0.87*5)+(0.13*15)=6.3).

3.1.3 Calculating the implied c^{ε} and c^{m}

When exiting firms liquidate, they usually sell off their entire capital stock. At the moment it liquidates, the firm's value is qk_1. Therefore as a fraction of that value, the costs are

$$\frac{1}{qk_1}\psi(1)\,k_1 = \frac{c^{\varepsilon}}{2q} = 0.35,$$

where the first equality follows from (17), and the second reflects our estimate of 0.35 for average exit costs. Thus $c^{\varepsilon} = (0.7)q$. We measure q as the ratio of the average market-book values of target and exiting firms to the average market-book value of acquirers.[8] The time series average of this measure of q over the period from 1974 to

[8] We use the Compustat files to compute firm q's, and define market value as the sum of common equity at current share prices (the product of items 24 and 25), the book value of preferred stock

2001 is 0.899. This results in the estimate of 0.63 for c^{ε}.

At the moment that a firm is acquired, its value is just k_2. Therefore as a fraction of that value, the costs are

$$\frac{1}{k_2}\phi\left(m\right)k_2 = \frac{c^m m^2}{2} = 0.063,$$

where the first equality follows from (17), and the second because 0.063 is our estimate of average merger costs. Thus $c^m = \frac{0.126}{m^2}$. We measure m by pooling the population of mergers from 1890 to 2003 and computing the mean of the ratio of the market values of targets to their acquirers. This ratio is 0.5, which results in a value of about 0.51 for c^m.

3.1.4 Setting other quantities of interest

In our simulation, the date-0 initial conditions are

$$k_1 = 1 \quad \text{and} \quad k_2 = 0,$$

and the other boundary conditions are

$$k_{1,T} = 0, \tag{18}$$

and

$$q_T = 1. \tag{19}$$

Next, from (16) and because $\sigma = 1$,

$$\frac{x_{2,T}}{k_{2,T}} = z_2 - \rho, \tag{20}$$

which we impose on the simulation.

The simulation requires that we get the path of q_t correctly. Since (14) is a simple differential equation, all we need is the right value of q_0. That value of q_0 has to be such that at date T (18), (19) and (20) must all be met. The simulation procedure we used chooses q_0 based on these criteria. As a double check, we plugged the q_0 back into the budget constraint of the consumer and made sure that it held: The present

(item 130), and short- and long-term debt (items 34 and 9). Book values are computed similarly, but use the book value of common equity (item 60) rather than the market value. Since company coverage within Compustat is very thin before 1972, we begin to compute Q's at this time. We count firms that disappear from Compustat as targets or exits, but only if the firm has been on the files for at least two years. Thus, our series for $\bar{q}$ begins in 1974. We omitted q's for firms with negative values for net common equity from the annual averages since they imply negative market-book ratios, and eliminated observations with market-book values in excess of 100, since many of these are likely to be serious data errors.

value of consumption as of date zero (just *after* the shock) equals wealth, which is just $q_0 k_{1,0}$. Since $k_{1,0} \equiv 1$, the intertemporal budget constraint reads[9]

$$q_0 = \int_0^T \exp\left(-\int_0^t r_s ds\right) c_t dt + \exp\left(-\int_0^T r_s ds\right) \frac{c_T}{\rho}, \tag{21}$$

where $r_s = z_2 + \pi^m(q_s) - \delta$.

We assume a discount rate (ρ) of 5 percent per year, and a depreciation rate for capital (δ) of 8 percent per year. When the new technology arrives, it raises the rate of growth from $z_1 - \rho = 0.01$, or one percent per year before the transition, to $z_2 - \rho = 0.015$, or 1.5 percent per year after the transition. This is consistent with standard estimates of the growth of consumption over the 20th century. For $z_2 - z_1$, which we set at 0.005, we consulted various studies of productivity-enhancing effects of takeovers. For the U.S., Maksimovic and Phillips (2001, p. 2053) find that the productivity of a target's plants rises by two percent between year -1 and year +2 surrounding the takeover date. For the United Kingdom, Harris, Siegel, and Wright (2002) find a larger effect. These improvements are probably transitory in fact whereas in our model the rise in productivity is permanent. As a compromise, we settled on half of a percent.

3.2 The baseline simulation vs. the data

The simulated series.—Our main interest is in how the diffusion of the new technology is implemented. The three ways in which k_2/k_1 grows are:

1. *Acquisitions.* Relative to market capitalization, acquisitions are

$$M = \frac{qmk_2}{k_2 + qk_1}. \tag{22}$$

2. *Exits.* Relative to market capitalization, exit is

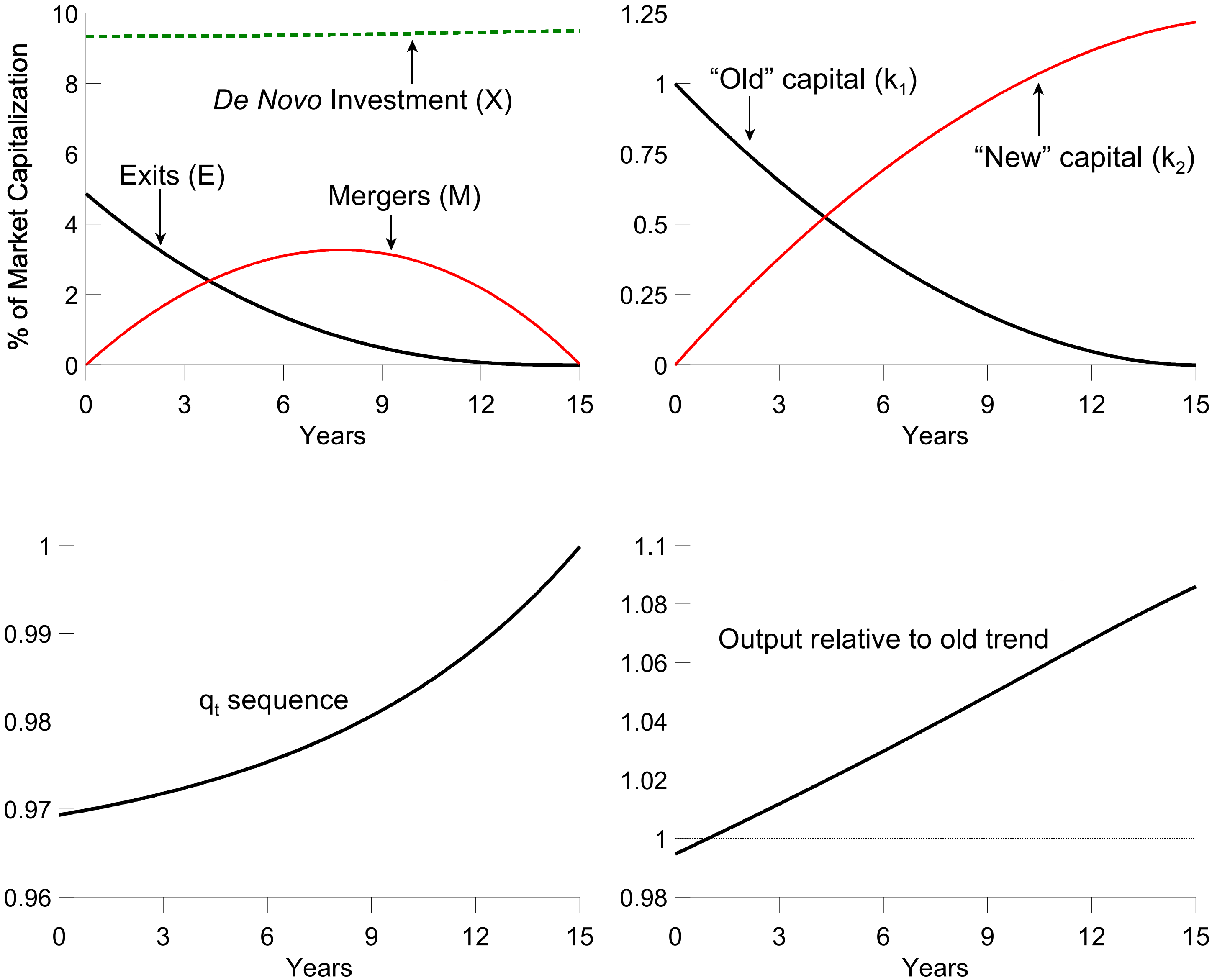
$$E = \frac{q\varepsilon k_1}{k_2 + qk_1}, \tag{23}$$

   and E must decline on average from ε at $t = 0$ to zero at date T.

3. *De novo investment.*

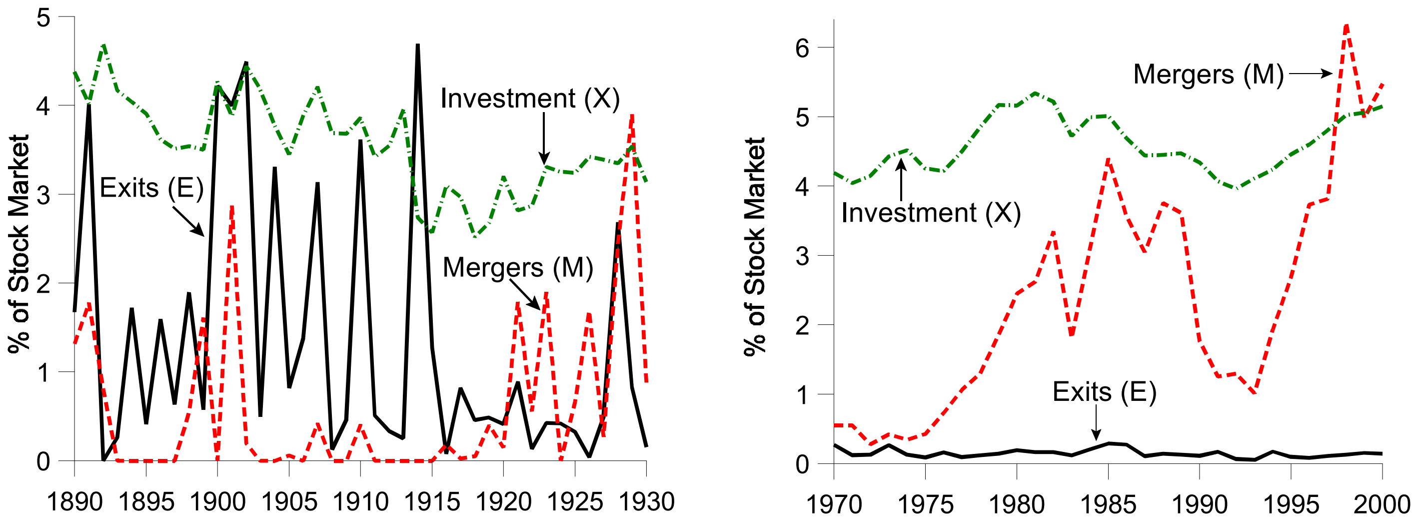
$$X = \frac{x_2}{k_2 + qk_t}.$$

[9] because for $t \geq T$, $r - g = (z_2 - \delta) - (z_2 - \delta - \rho) = \rho$.



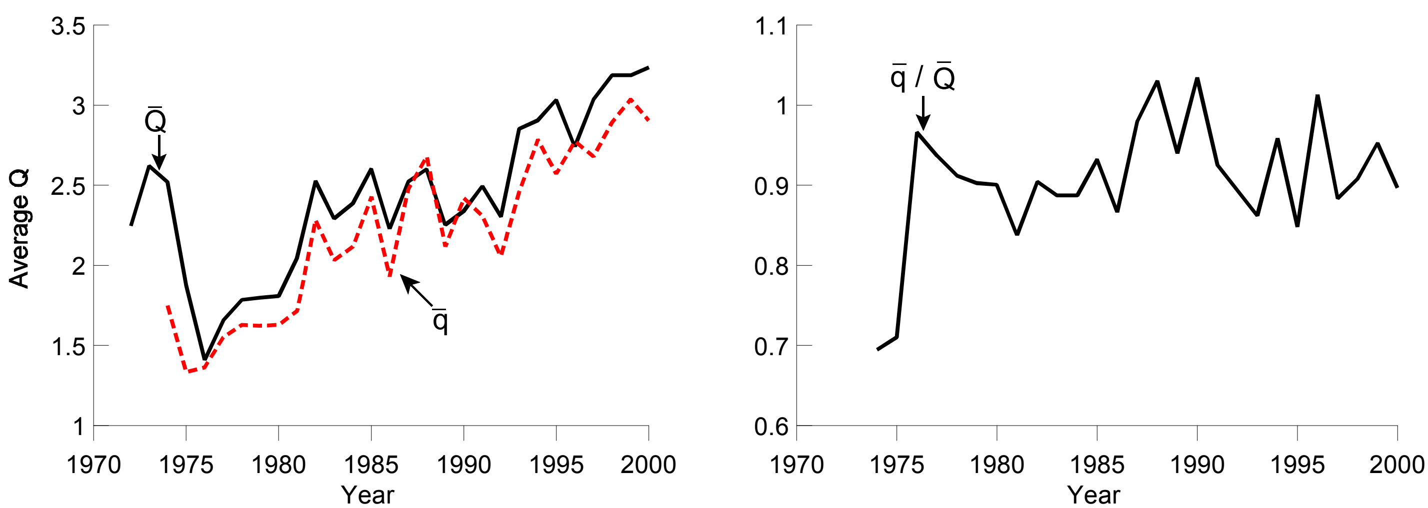
Model settings:
$z_1 = 0.140$, $z_2 = 0.145$, $c^{\varepsilon} = 0.63$, $c^{m} = 0.51$, $\rho = 0.05$, $\sigma = 1$, $\delta = 0.08$.

Figure 3. Transitional dynamics I.



(a) electrification period (b) IT period

Figure 4. The values of exiting firms and merger targets in two technological epochs.



(a) Q's by investment subgroup (b) the ratio of exiting and target firm q's to acquirer Q's

Figure 5. Prices of the two types of capital in the IT transition.

Figure 3 presents results from the calibrated model. The upper left panel shows the time paths of mergers (M), exits (E), and *de novo* investment (X) during the transition that follows the productivity shock. Figure 4 shows the empirical counterparts for the electricity (1890-1930) and IT (1970-2000) periods.[10]

Since k_1 is decreasing, exits (E) should fall over the transition. Figure 4 shows that exits have a slight negative trend, though the T-statistics in regressions of exits on trend are only 1.27 for the electricity epoch and 1.6 for the IT period. Exits average 1.33 percent of stock market capitalization for the electricity period, 0.15 percent for the IT period, and 0.60 percent for 1890-2003. In our simulation, exits average 1.40 percent of stock market capitalization over the transition, which is closer to observed exits for the electricity period.

Acquisitions should be inverted U-shaped in that a merger wave must begin and end at zero. Figure 4 shows that mergers crest in the data during the second half of each transition, with target firm values averaging 0.61 percent of stock market capitalization for the electricity period, 1.97 percent for the IT period, and 1.03 percent from 1890-2003. Target values average 2.18 percent of stock market value in the simulation, which is closer to observed target values for the IT period.

We also simulated *de novo* investment (X) in Figure 3, but in practice we do not know the investment for firms that actually traded on the stock market. For the economy as a whole, investment net of residential structures averaged 10.5% of GDP for 1890-1930 and 11.5% for 1970-2000.[11] These shares are a few percentage points higher than in our simulation, but the units are not the same. If the aggregate capital stock was about three times nominal output from 1890-1930 and about two and a half times output from 1970-2000, we can divide each average by these multiples to express investment as shares of stock market capitalization, assuming that listed firms form their capital stocks in the same way as unlisted ones. The resulting investment shares of 3.5% for 1890-1930 and 4.6% for 1970-2000 are less than half of those in our simulation. The simulation also shows X to be only slightly upward sloping: It rises by 1.7 percent overall. Investment in panel (b) of Figure 4 for the IT period shares this upward trend, but the trend is slightly downward for electrification in panel (a).

[10] We chose 1890 as the start of the electrification epoch because this is when electric power began to see active use in lighting and in industry. The startup of the hydroelectric power facility at Niagra Falls in 1894 was also a pivotal event in the "arrival" of electrical technology. The diffusion of electricity in the home and in industry proceeded rapidly in the first three decades of the 20th century, but then slowed down dramatically around 1930 – shortly after the stock market crash of October 1929. For the IT epoch, we chose 1970 for the starting year because this is the time that Intel became ready to introduce the first microprocessor chip. We close the IT period at the end of 2000 because this is closest to the "dot-com" bust of March 2001. Jovanovic and Rousseau (2003) provide further discussion on the dating of these GPTs.

[11] We obtain private domestic fixed investment and its deflator for 1970-2000 from the August 2002 issue of the *Survey of Current Business* (Table 1, pp. 123-4, and Table 3, pp. 135-6) and exclude non-farm residential investment. We use Kendrick (1961, Table A-IIa, column 7) for 1890-1930, and subtract residential nonfarm construction from worksheets underlying Kuznets (1961, Table T-11).

Using the average market-to-book ratios of exiting and target firms as a proxy for q, panel (a) of Figure 5 shows that q has been rising during the IT episode. But so has Q when measured as the average market-to-book values of acquirers, and this flatly contradicts the implication that $Q = 1$.[12] The model could explain values of Q in excess of unity if we put in adjustment costs for *de novo* investment, but this complicates the algebra and probably would not affect the implications about the time path of q/Q. Moreover, part of the rise in both q and Q may be due to the rising importance of unmeasured components of k_2 that are not on the firms' books. It is better, therefore, to concentrate on the ratio q/Q. In the theory, Q is unity and so

$$q = \frac{q}{Q}.$$

The theory predicts a monotonic rise in this ratio. Panel (b) of Figure 5 shows that the ratio has indeed risen, but much faster than the simulation in the lower left panel of Figure 3.

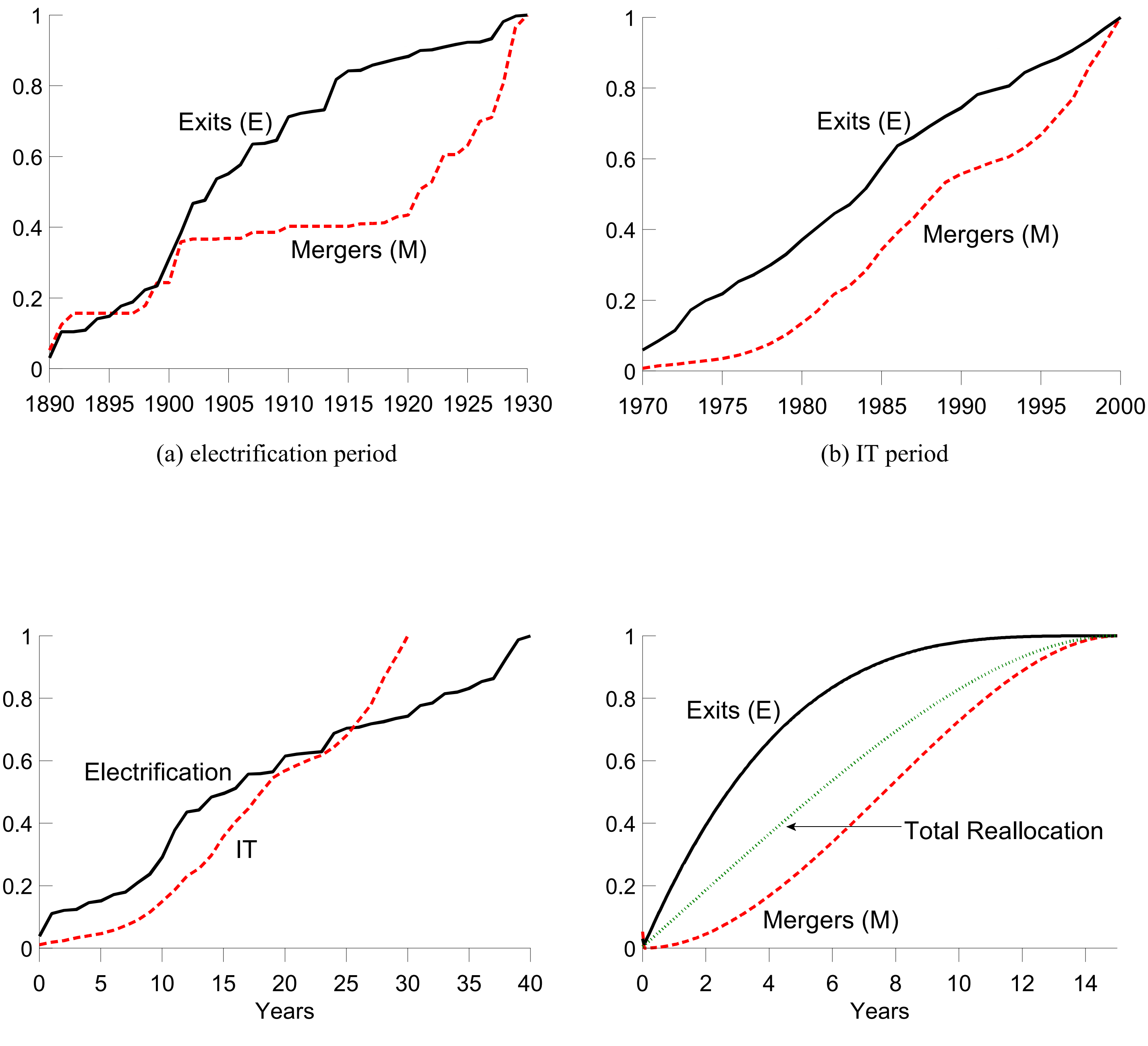
The lower right panel of Figure 3 shows the path of output during the transition relative to what it would have been in the absence of the productivity shock. Reallocation through exits and mergers appears here to come at some cost to the level of output in the short term, but by the end of the first year it has already surpassed the level achievable under the old path.

Do exits lead mergers?—The model implies that exits should lead mergers. This is indeed so. Exits are downward sloping in the data for the electricity period and mergers dominate later in the reallocation wave. The mean of the series for cumulative exits occurs in 1903, about one-third of the way into the reallocation wave, and the mean for mergers occurs in 1910, at about the halfway point. Exits also fall during the IT period, with mergers growing in intensity as the wave progresses. In this case, the mean of the series for cumulative exits occurs halfway into the wave in 1983, and two-thirds of the way into the wave in 1988 for mergers. Thus, the means of these distributions suggest that exits led mergers in both transitions, and that reallocation in general occurred later in the IT period than for the electrification period.

Panels (a) and (b) of Figure 6 show the normalized cumulative distributions of mergers and exits by year for each of the two reallocation epochs. For mergers this is

$$\left(\sum_{\tau=1}^{T} M_\tau\right)^{-1} \sum_{\tau=1}^{t} M_\tau$$

[12] We use the Compustat files to compute firm q's, and define market value as the sum of common equity at current share prices (the product of items 24 and 25), the book value of preferred stock (item 130), and short- and long-term debt (items 34 and 9). Book values are computed similarly, but use the book value of common equity (item 60) rather than the market value. Since the company coverage within Compustat is very thin before 1972, we begin to compute q's at this time. We count firms that disappear from Compustat as targets or exits, but only if the firm has been on the files for at least two years. Thus, the series for $\bar{q}$ and $\bar{q}/Q$ begin in 1974. We eliminated observations with market-book ratios in excess of 100, since many of these are likely to be serious data errors.



(a) electrification period

(b) IT period

(c) total reallocation in the two epochs

(d) simulated values

Figure 6. Normalized cumulative distributions of exits, mergers, and total reallocation.

for $\tau = 1, ..., T$. For exits, this is

$$\left(\sum_{\tau=1}^{T} E_\tau\right)^{-1} \sum_{\tau=1}^{t} E_\tau.$$

At the start of the electricity period in panel (a), mergers and exits proceed together, but exits begin to dominate mergers just as the end-of-the-century merger wave draws to a close around 1902. It is not until the 1920's that mergers begin to catch up again. In panel (b) for the IT period, exits always lead mergers despite bursts of merger activity in the mid-1980's and late 1990's.

Panel (c) of Figure 6 shows the cumulative distributions of reallocative activity for the two epochs[13], defined as

$$\left(\sum_{\tau=1}^{T} (M_\tau + E_\tau)\right)^{-1} \sum_{\tau=1}^{t} (M_\tau + E_\tau).$$

The electricity period experienced more reallocation early in the epoch than the IT period, which had a later surge of reallocation associated primarily with mergers. Despite this difference, however, the patterns of reallocation are remarkably similar across the epochs.

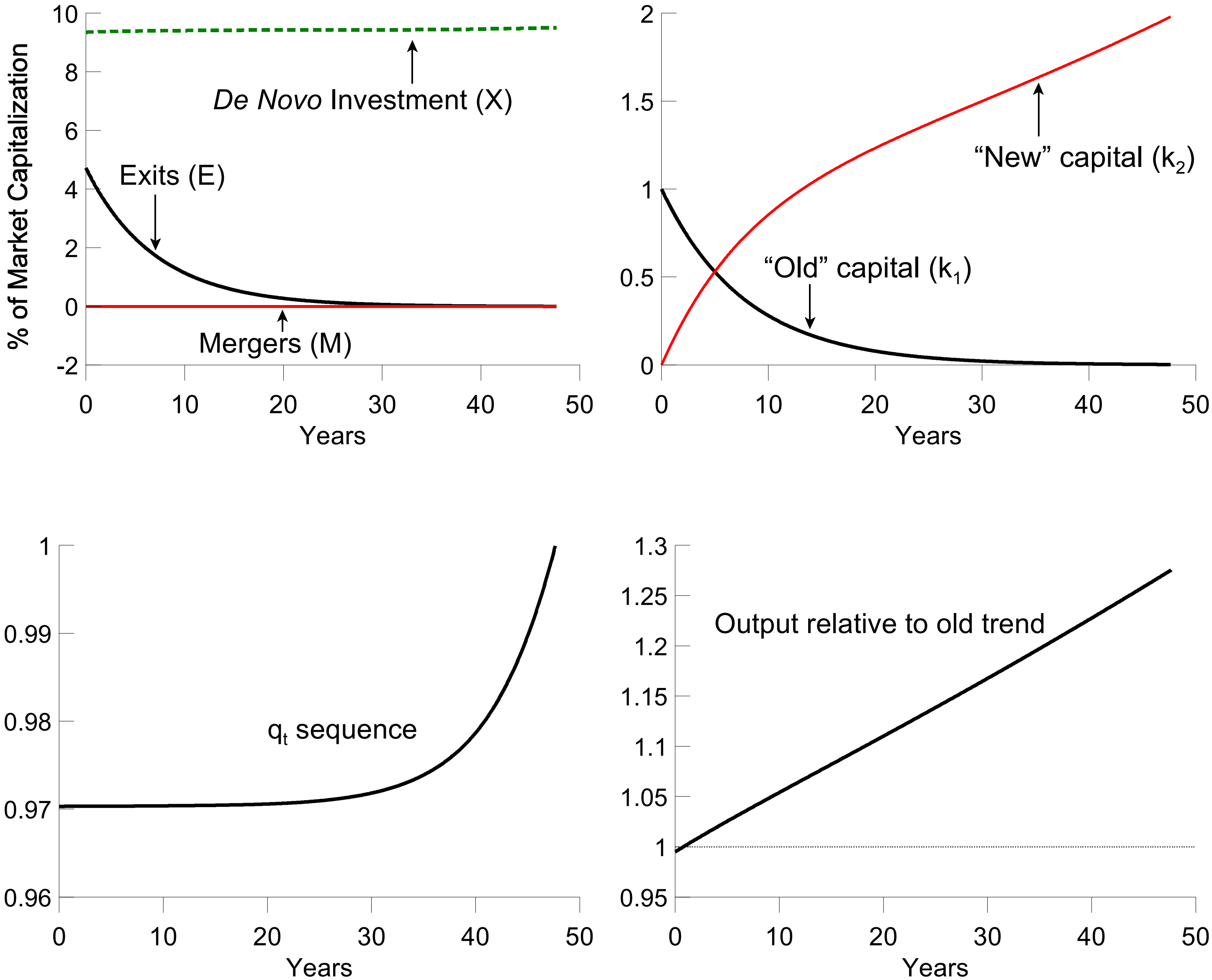
Panel (d) shows the same normalized cumulative distributions for exits, mergers, and total reallocation from our baseline simulation. Exits in the simulation follow a pattern quite close to that of the electrification period, while mergers look more like the data for the IT period.

We conclude that the patterns of reallocation obtained from the baseline simulation are qualitatively similar to those seen in the data from the electricity and IT periods, and that even with a single set of parameter choices the model can explain a good deal of the complex process of reallocation that has characterized the U.S. economy across the 20th century. But puzzles remain: Figure 4 shows that exits were several times as important as acquisitions during the electricity period, with the opposite being the case during the IT period. We do not explain this reversal. Two possibilities come to mind though. Exits may have declined because teamwork and organization capital are now more important so that the cost of destroying them has risen. And mergers may have risen because the stock market is much thicker today than 100 years so that it is easier to find a suitable partner listed.

3.3 An economy without mergers

Atje and Jovanovic (1993), Levine and Zervos (1998), and Rousseau and Wachtel (2000) suggest that the presence of deep and liquid equity markets can have positive

[13] The cumulative distribution for the IT epoch (1970-2000) ends in panel (c) before that of the electricity epoch (1890-1930) because the IT transition is ten years shorter using our dating of the GPT periods.



Model settings:
$z_1 = 0.140$, $z_2 = 0.145$, $c^{\varepsilon} = 0.63$, $c^{m} = \text{infinity}$, $\rho = 0.05$, $\sigma = 1$, $\delta = 0.08$.

Figure 7. Transitional dynamics II.

effects on long-run economic performance. One channel for these effects could be through the ability to reallocate capital via mergers, since it is presumably more costly to identify targets and complete acquisitions in the absence of an equity market and the accompanying informational and transactional economies.

Figure 7 presents a simulation of our model with mergers assumed to be infinitely costly ($c^m = \infty$). All other parameters are as in the baseline. The upper left panel shows that, as might be expected, this change shuts down mergers as a reallocative mechanism, forcing more activity to occur through exits and *de novo* investment. The main effect of this change is not increases in the levels of exits and new investment, however, but rather a prolonging of the reallocation wave itself. Where the wave took 15 years to complete in the baseline simulation, it now takes 46.7 years – more than three times as long. Even here, exit activity slows down considerably after 20 years or so. This leaves it to *de novo* investment, which begins at a level that is 0.16 percent higher than in the baseline simulation before converging to its steady state path of 9.5 percent of the stock market, to bring about the transition to the new capital over a much longer time span. *De novo* investment rises by even less than in the baseline simulation – only by 1.54 percent overall. The role of *de novo* investment is also clear in the upper right panel of Figure 7, which shows that the level of new capital is 60 percent higher by the end of the transition than it is in the baseline case.

The sequence for q_t in the lower left panel of Figure 7 progresses much more slowly toward unity with $c^m = \infty$ than in the baseline simulation, even though it begins at a higher level. The latter fact may seem surprising because mergers form one part of the demand for k_1 and prohibiting mergers would for that reason be expected to lower q_0. But prohibiting mergers also prolongs the transition and lowers the interest rate during the transition by the amount $\pi^m(q)$. Thus the services of k_1 are discounted at a lower interest rate and q_0 rises. Figure 10 in the Appendix shows that q_0 can be larger with $c^m = \infty$ because q^* (defined after [14]) is larger.

Figure 8 shows the ratio of output in the baseline model to that in the second simulation. This offers some idea of the value of a market for mergers to overall economic performance during the period of reallocation and thereafter. As also suggested by a comparison of the lower right panels of Figures 3 and 7, Figure 8 shows output declining relative to its pre-productivity-shock trend more strongly in the baseline simulation than when $c^m = \infty$ (i.e., when mergers are shut down). Output quickly recovers in the baseline case, however, exceeding the level of output in the second simulation after only nine years and continuing to grow more rapidly for the next five. By the fifteenth year, output growth in the baseline has fallen back to its new steady state rate of 1.5 percent per annum. With $c^m = \infty$ in the second simulation, output growth stays above the steady state rate of 1.5 percent until it very gradually converges as the transition ends – 46.7 years after the shock. The ratio remains constant at this point since both output series grow at the same rate.

How much would an underdeveloped economy want to pay for having a developed stock market? Mergers are largely a stock-market phenomenon, and we estimate this

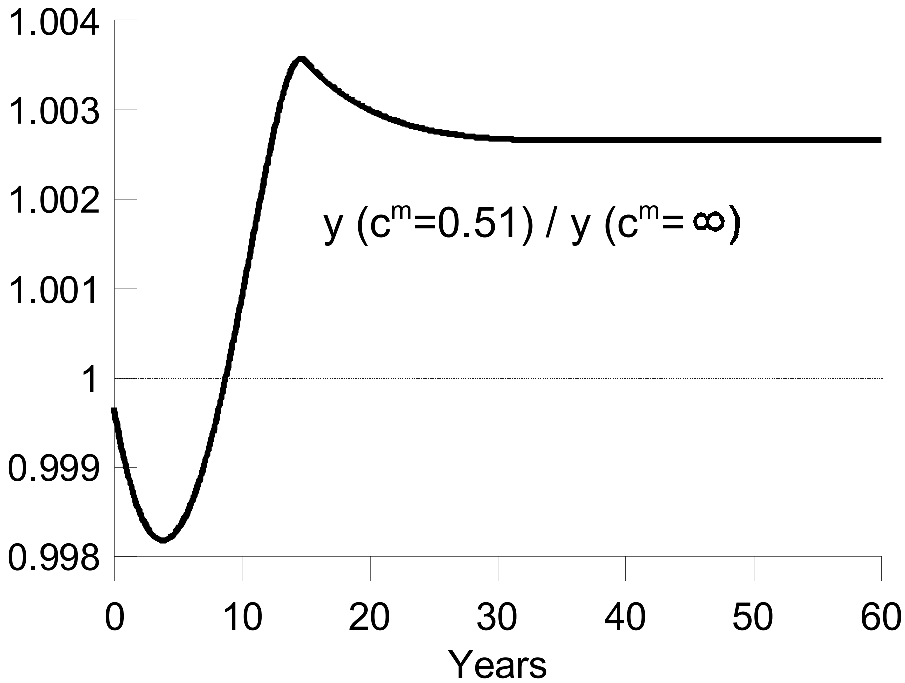


Figure 8: The ratio of the outputs from the two simulations.

component of financial development. The overall effect of the merger market on the level of output is small in our simulations – only 0.27 percent higher than in the case with $c^m = \infty$. The present value of this gain at the time of the productivity shock can be computed as

$$\int_0^\infty e^{-rt} \left(y_{1,t} - y_{2,t} \right) dt$$

where

$$r = z_2 - \delta$$

is the interest rate prevailing in the merger-less economy. Using our parameter values of $z_2 = 0.145$ and $\delta = 0.08$, this integral is positive at 0.00387, I.e., about 2.8 percent of date-zero output (which is $z_1 k_{10} = z_1 = 0.14$). Since this value is calculated at the exact time that the new technology arrives, the value of mergers (which play no role in a one-technology equilibrium) is ordinarily even smaller than that. But this is an underestimate of the merger component of financial development, because mergers happen for other productive reasons such as shocks to management quality as modeled in Jovanovic and Rousseau (2002). Moreover, financial development brings other benefits, such as promoting the accumulation of capital, directing new investment funds to the more productive uses, and improving risk sharing arrangements.

4 Other evidence

In this section we report evidence of a more general nature, but still helpful for evaluating the model.

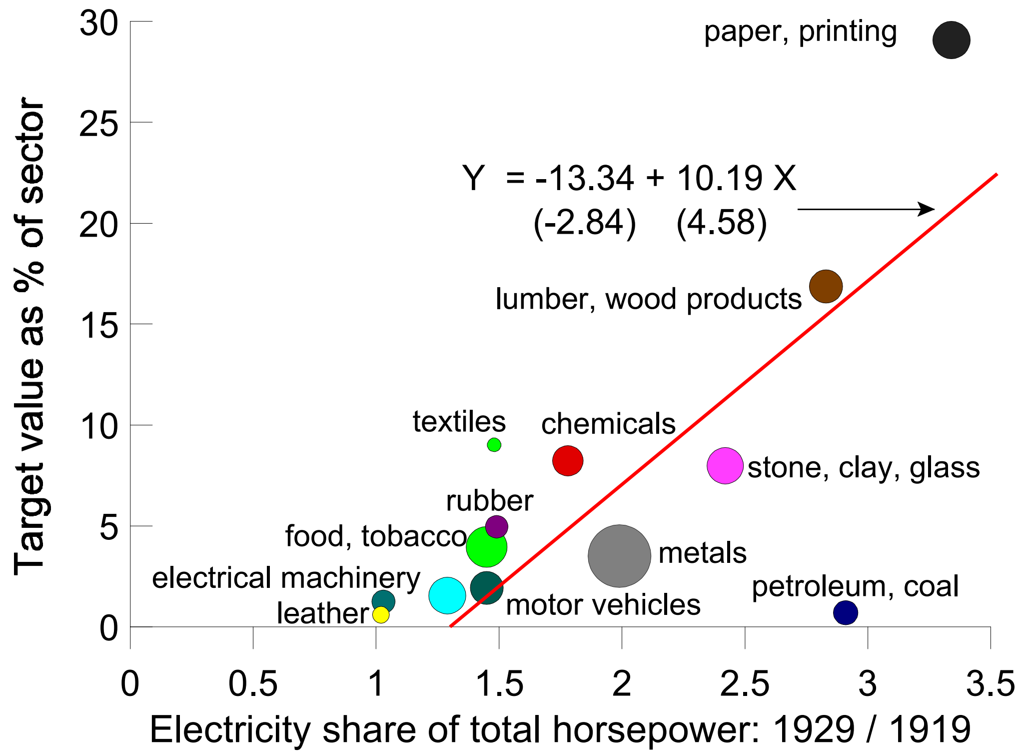
Acquisitions, exits and IPOs by sector If m and ε are performing the same sort of reallocative function, then they should be positively correlated over sectors. It turns out that they are. The rank correlations between exits and initial public offerings (IPOs) on the one hand and acquisitions on the other, with ranks based upon the percentage of each in total sector value (with the merger samples as defined in fn. 3) are given below.

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

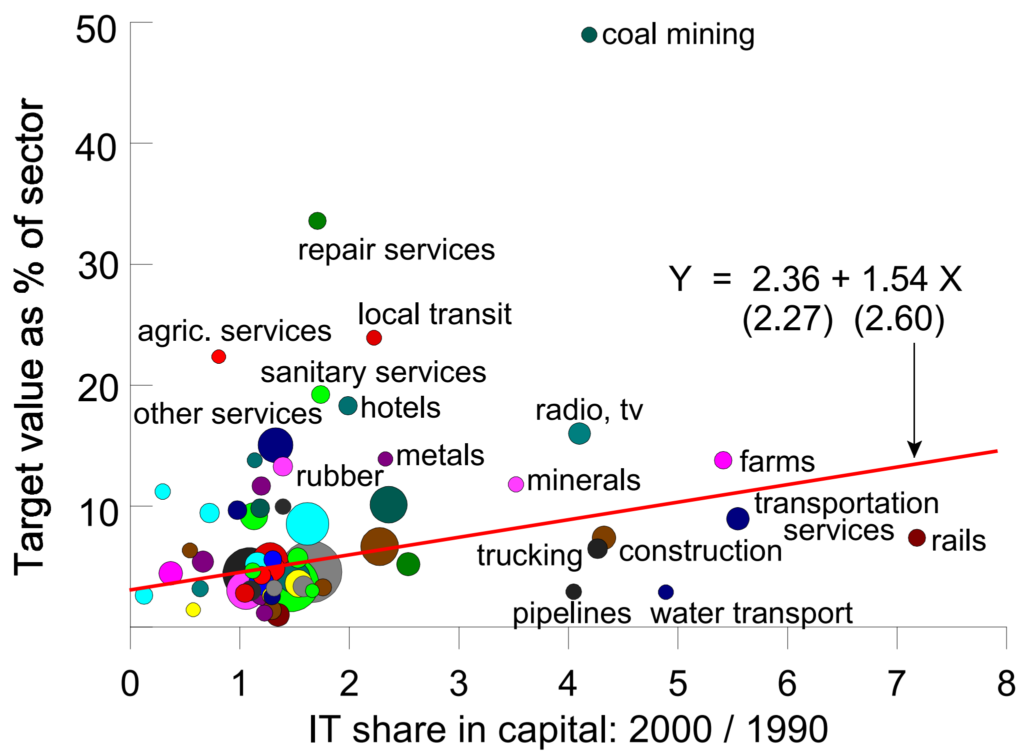
We include the rank correlations between mergers and IPOs because much of the exiting capital in the U.S. economy is likely to wind up back on the stock market through new security issues. Both sets of correlations fit the model well, with all three forms of reallocation highly correlated across sectors.

Acquisitions and sectoral exposure to GPTs Andrade *et al* (2001) argue that technological and deregulation shocks are behind the merger waves in the high-merger sectors in the 1980s and 1990s. If that is so, then the arrival of a new GPT, which by definition applies to most sectors, should prompt an economy-wide merger wave. But 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 fixed asset tables of the Bureau of Economic Analysis (2002). The acquisitions that we report are for 1925-30 and 1997-2000 (the merger waves as



(a) electricity period



(b) IT period

Figure 9. Target values vs. changes in GPT shares over 10-year periods by sector.

defined in Figure 1).[14] That is, we look at the growth of the GPT shares over 10-year periods and then report acquisitions during the end-of-period wave. 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.[15]

Figure 9 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, we got

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

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

5 Related work

Boldrin and Levine (2001) also have a technology for converting old capital to new. Since they do not allow goods to be converted into new capital one for one, their results are different. Holmes and Schmitz (1990) discuss the selling of capital by inventors to managers which resembles the two conversion activities that we emphasize here. Mortensen and Pissarides (1998) look at constant growth, not at transitions, and focus on the labor market, but their work is similar in that they have two modes of job improvement that are similar to the two that we have modeled. Caballero and Hammour (1994) study transitions at business-cycle frequencies. Finally, Atkeson and Kehoe (2001), Greenwood and Yorukoglu (1997) and Hornstein and Krusell (1996) study transitions, but they do not focus on adjustment costs like we do. Eisfeldt and Rampini (2002) have recently found that reallocation of capital and the dispersion of

[14] 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 9 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 9 reflects activity among exchange-listed firms only.

[15] In other words, for the electrification period, 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) that resides in each sector.

Q are both pro-cyclical. Jovanovic and Rousseau (2002) show that the reallocation of capital via merger also responds to dispersion in Q.

Shleifer and Vishny (1992) argue that merger waves are driven by liquidity which allows the re-assignment of capital among owners to proceed more smoothly. This suggests that one may augment the adjustment-cost functions ϕ and ψ to include a financial factor. Faria (2002) fits a model related to ours to the Telecom merger wave of the 1990s. Toxvaerd (2002) models a merger wave as arising when firms rush to buy so as not to be left without a target.

On the productivity-enhancing role of takeovers – i.e., on the question of why merged capital and exiting and re-entering capital experiences a rise in efficiency from z_1 to z_2 – we know that exiting plants are less productive than the average plant and less productive than the average entering plant (Baily, Hulten, and Campbell 1992). A multi-plant firm is likely to sell off its least productive plants (Maksimovic and Phillips 2001). Takeovers do seem to have beneficial real effects. Martin and McConnell (1991) find that managers of takeover targets are more than four times more likely to be replaced than those same managers before the firm had been selected as a target. After a takeover their turnover rate jumps from 10 percent to 40 percent or so. McGuckin and Ngyen (1995) and Schoar (2000) find that the productivity of acquiring firms' plants falls and that the productivity of the targets' plants rises following a takeover. Lichtenberg and Siegel (1987) find that plants changing owners had lower initial levels of productivity and higher subsequent productivity growth than plants that did not change hands. The above evidence is for the United States. In the United Kingdom things work roughly the same way, as Harris, Siegel, and Wright (2002) found in their study of 36,000 manufacturing plants of which nearly 5,000 were involved in a takeover from 1994 to 1998.

Lang, Stultz, and Walkling (1989) and Servaes (1991) find that the mergers that create the most value are those between high-Q bidders and low-Q targets. Merger announcements do tend to lead to declines in the prices of acquirer shares. But Jovanovic and Braguinsky (2004) show that when firms have private information about the quality of the capital that they own, the bidder discount is consistent with takeovers being constrained efficient, as they are in the present model.

6 Conclusion

While mergers are probably driven by a variety of motives, one role that they play, this paper argues, is that of reallocation of assets toward the more efficient firms. If this is correct, major technological change should lead to merger waves. We studied two GPT epochs – electricity/internal combustion and IT – and found that this seems to have been the case. We also provided an estimate of the value – though only in the context of ushering in new technology – that the merger mechanism adds.

The model's two main positive implications – that exits and mergers should rise after a shock, but that exits should lead mergers – are borne out by the data. On the other hand, the fit of the model is far from perfect. We do not explain the conglomeration wave of the 1960's, and the wave of 1900 occurs earlier than our model suggests that it should have. Nor do we explain why mergers have become the dominant reallocation mode, at the expense of exits. Thus the scope for more research is broad. So far we believe we have shown that the reallocation motive explains a fair portion of the mergers and exits in the last century.

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7 Appendix

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

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

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

$$\frac{\partial H}{\partial m} = 0 = -U'(c)\, \phi'(m) + Q^* - q^* \tag{24}$$

$$\frac{\partial H}{\partial \varepsilon} = 0 = -U'(c)\,\psi'(\varepsilon) + Q^* - q^* \tag{25}$$

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

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

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

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) and (11),

$$Q = 1,$$

which is the same as (12),

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

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

$$\phi'(m) = 1 - q,$$

$$\psi'(\varepsilon) = 1 - q,$$

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

and

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

or,

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

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

This reduces to a single differential equation for q;

$$\frac{\dot{q}}{q}=z_2+\pi^{m}\left[q\right]-\frac{\left(z_1+\pi^{\varepsilon}\left[q\right]\right)}{q}, \tag{26}$$

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

$$\left(z_2-\pi^{m}\left[q\right]\right)=\frac{\left(z_1+\pi^{\varepsilon}\left[q\right]\right)}{q}$$

for all $t\in[0,T]$. Under mild conditions (e.g., if ϕ and ψ are the same function),

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

and the steady state is unstable. That is,

$$q \gtrless q^* \quad \Longrightarrow \quad \frac{\dot{q}}{q}\gtrless 0.$$

Therefore we must have

$$q_0>q^*,$$

or else q_t could not converge to unity. Now, if this were so, (26) would imply that

$$\lim_{t\to T}\frac{\dot{q}_t}{q_t}=z_2-z_1$$

because $\lim_{q\to 1}\pi^{i}\left(q\right)=0$.

One caveat: The above ignores the constraint $x_2>0$. If the upgrading technology 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. We have ignored this constraint, and the solution we derived would not be valid if ψ and ϕ were low for large-enough values of ε or m. Our simulations always have $x_2>0$, so this is not a practical problem.

7.2 Diagrammatic exposition of q^* and q_0

Here we elaborate on the point about q_0 being higher when $c^m=\infty$. Figure 10 shows that q_0 can be larger with $c^m=\infty$ because q^* (which is defined right after [14])is larger. For the baseline simulation, q^* solves the intersection between the red line and the brown line, whereas with $c^m=\infty$ the q^* solves the intersection between the blue line and the brown line. And q_0 must be above q^*.

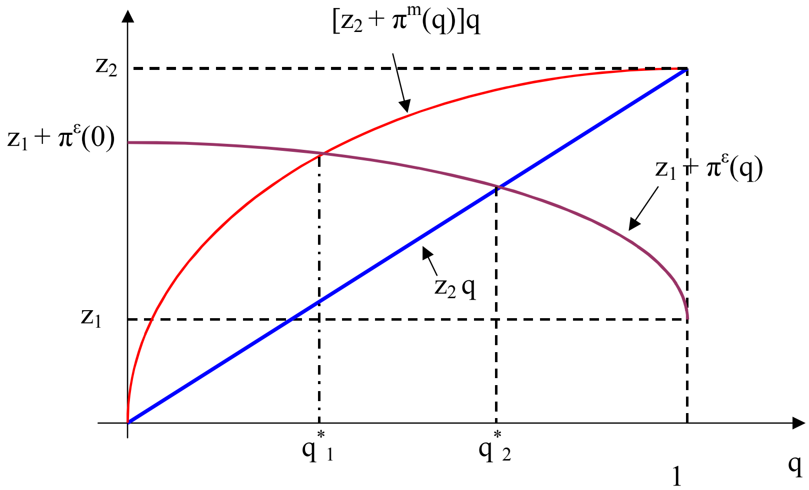

Figure 10: The determination of q^* in the two simulations