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Discussion

Comment on "Aggregate returns to scale and embodied technical change: theory and measurement using stock market data"☆

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1. Comment

Technological change is central to the Solow growth theory, yet the model's very elegance precludes capturing the richness of the transformations that we observe. After all, constant growth in the model's single technology parameter "A" imposes smoothness and predictability on what are in fact more visceral processes that evolve quickly at times, slowly at others, and often with sharp discontinuities, all the while demonstrating little predictability. The recent literature on general purpose technologies (GPTs) speaks to this issue (and others), and the contribution by John Laitner and Dmitriy Stolyarov takes the important step of generalizing the Solow framework to allow for fluctuations and discontinuities in the processes through which new technologies arrive.

After calibrating their general equilibrium model of capital reallocation to U.S. macroeconomic data from 1953 to 1995, the authors find that parameterizations with a single, "punctuated" technology shock occurring sometime between 1972 and 1974 match actual stock market performance and interest rate behavior more closely than specifications with continuous change, and even better than ones that combine punctuated and continuous components. They reason that the punctuated model works well because it reflects the information technology (IT) revolution, which "arrived" at about this time. The model is also useful for growth accounting exercises, which suggest that the IT revolution raised aggregate TFP permanently by about 20 percent.

☆Comment on "Aggregate returns to scale and embodied technical change: theory and measurement using stock market data" by John Laitner and Dmitriy Stolyarov prepared for the April 2003 Carnegie–Rochester Conference.

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The model's ability to handle more complex formulations of the "A" parameter while retaining the Solow model's equation of motion for capital is impressive, but the discipline required to accomplish this comes at some cost. The time paths of the simulated interest rates that characterize the model's "best" fits (see the lower panels of Figs. 3 and 4 in the Laitner–Stolyarov paper) illustrate this. By imposing a single technology shock in 1972, for example, the model captures the sudden decline and rapid recovery of interest rates at that time, but there is considerable variation in interest rates at other times that the specification does not capture. My comment will touch upon areas where the trade-off between tractability and consistency with the empirical facts seems most severe, and suggest some ways in which further research might enrich our understanding of the processes through which capital changes hands.

1.1. Handed-down capital?

The model includes a frontier technology that is embodied equally in all new capital, which includes both physical capital and intangible stocks of applied knowledge. A firm can operate only one vintage of the composite capital, and only some firms choose to update it as the frontier expands. The capital of non-updating firms becomes less valuable because it produces less of the consumption good when combined with a given amount of labor than units of the frontier capital. The consumption good can be exchanged for frontier capital on a one-for-one basis, but it trades for more than one unit of non-frontier (i.e., older) capital. All firms and industries are symmetric. Firms adopt new technologies to earn temporary rents, but capital prices of all vintages adjust immediately so as to eliminate profits. For example, if one unit of frontier capital and two units of labor can produce one unit of the consumption good at time t, there is a quantity $v > 1$ units of vintage $t - i$ capital that could also combine with two units of labor to produce an identical unit of the consumption good. The price of these $v > 1$ units of older capital would be unity, as would the price of frontier capital.

When the frontier moves out some firms sell their old capital on the used market and buy frontier capital, while others buy old capital in the used market in quantities needed to remain competitive with frontier firms. That is, old capital becomes concentrated in firms which apply more of it to a given amount of labor. The zero-profit condition allows all firms to share equally in the benefits of technological change whether they choose to adopt the frontier technology, stay with and augment their non-frontier capital, or replace it with capital of a newer but non-frontier vintage. The result is that all firms end up producing identical amounts of the same consumption good in every period.

A key question to ask, then, is whether this "handing-down" of capital is consistent with the history of technological change in the United States. The short answer is that it is not. One reason for this is that the model has no explicit role for mergers and acquisitions (M&A). Indeed, firm-level data from the Compustat database indicate that M&As are more important, at least among exchange-listed firms, in effecting the reallocation of capital than the used capital market. Fig. 1,

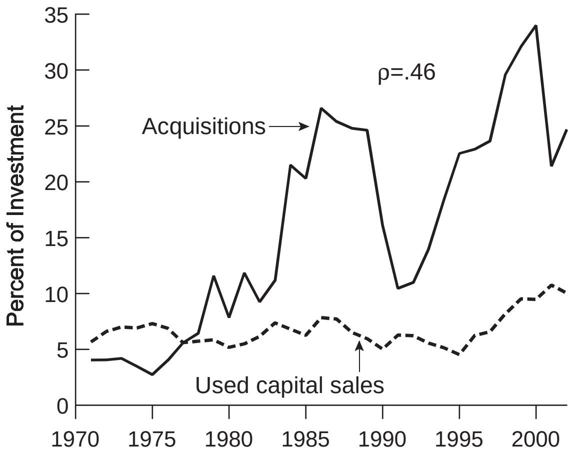

Fig. 1. Used and acquired capital as percentages of total investment, 1971–2002.

updated from Jovanovic and Rousseau (2002a, p.198), compares the value of capital reallocated through M&A targets with used capital sales since 1971 as percentages of total investment among listed firms. The correlation of 0.46 suggests they may well be alternative means of reallocation. Nonetheless, acquisitions often exceed used capital sales by a factor of more than three.[1]

The point here is that Laitner and Stolyarov embed the underlying technology parameter in the capital itself. This simplifies the analytics considerably, but embodiment in a composite capital shuts down one of the primary motives for reallocating by merger, that being to get less productive capital into the hands of better managers who can in turn make it more productive by applying it to better projects. In other words, reallocation might be described as a process by which frontier managers acquire old capital and ‘‘bring it back’’ to the frontier, rather than as a result of both physical capital and knowledge capital deteriorating as a bundle when new technologies arrive. Given the relative importance of mergers compared to used capital sales, a model with explicit ‘‘management capital’’ could much more easily capture this key feature of the U.S. financial landscape.

The tendency to reallocate capital through the widespread use of M&As did not just develop recently, but has figured prominently throughout the 20th century. Interestingly, the exit of firms and re-entry of their capital under new managements has been just as important, and especially for the period from 1890 to 1930. Fig. 2, modified from Jovanovic and Rousseau (2002b, p.3), shows the combined equity values of stock market entrants and de-listing firms divided by two and exchange-listed merger targets annually from 1890 to 2001 as percentages of total stock market

[1] Though used capital sales account for only about 5–10 percent of investment among listed firms in the U.S. economy, Shinohara (1962) reports a 50 percent share among small Japanese firms early in the postwar era. This finding, among others, suggests that Laitner and Stolyarov's model might be better applied to developing economies than to the United States.

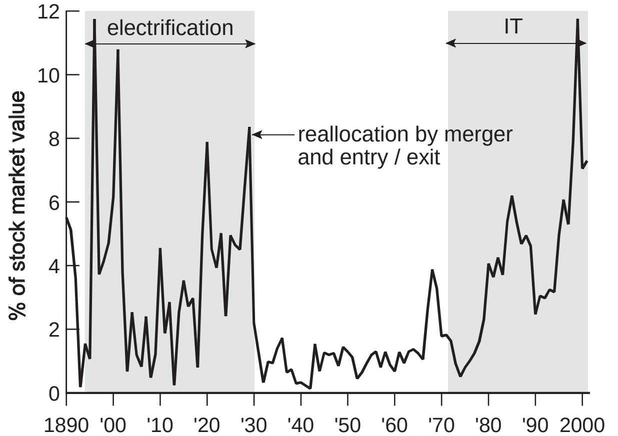

Fig. 2. The market value of stock-market entrants and de-listing firms divided by two, plus exchange-listed merger targets as a percentage of total stock market value, 1890–2001.

value.[2] The first component, entries and exits divided by two, is a rough measure of how much capital exits from the stock market and comes back under different ownership, or at least under a different name. When combined with the market capitalization of M&A targets, Fig. 2 reflects the amount of reallocation that has occurred outside of the used capital market in the U.S. economy over the long term. The shaded areas correspond to periods generally associated with the electrification of the U.S. economy and the IT "revolution."[3]

A few comments are in order. First, Fig. 2 shows that capital is in general not reallocated smoothly across incumbent firms, but rather through processes that involve firm births, deaths, and takeovers. In contrast, the authors use free-entry and zero-profit conditions to ensure that the number of firms in the economy stays constant. Second, though not shown separately in Fig. 2, exit and entry were the dominant methods of reallocating capital early in the century, while mergers, though significant around 1900 and in the late 1920s, became increasingly important as the century progressed. This may reflect the increasing capacity of the U.S. financial sector to facilitate reallocation by M&A in a cost-effective manner. Finally, if technological revolutions generate reallocation "waves," as Jovanovic and Rousseau (2002b) suggest, then the shading in Fig. 2 makes a case for there being only two of them in the 20th century, arriving nearly 80 years apart. Laitner and Stolyarov, on the other hand, assume in calibrating their model that such revolutions occur every

[2] Market values of targets and de-listings are recorded at the end of the year preceding the merger. Entrant values are from the end of the entry year. See Jovanovic and Rousseau (2002b) for details on the sources and methods used to build the reallocation series.

[3] The "electrification era" probably got started in earnest around 1894 with the opening of the Niagra Falls hydroelectric facility, and home adoptions of electricity had leveled off by 1930. The "IT era" probably started around the time that Intel developed the 4004 microprocessor in 1971, and by nearly all accounts continues to this day.

20–40 years. This gives their capital stock a more rapid rate of obsolescence than might be justifiable.

The handing-down mechanism also has implications for job separations since capital includes intangible stocks of applied knowledge. That is, the model implies that a major technological change should accelerate obsolescence in firm-specific human capital and lead to waves of reshuffling across firms. The authors do not consider this implication, but evidence from the Bureau of Labor Statistics for manufacturing, if anything, indicates that job separations were on the decline throughout the 1970s.

1.2. From model to data

The authors provide an innovative mechanism through which both continuous and revolutionary technological change can enter the Solow model. To summarize, technology grows at a constant rate, possibly zero, until a shock occurs that either (a) changes its growth rate, (b) changes its level, or (c) changes its level and subsequent growth rate. Shocks cause the stock market to decline because the value of non-frontier capital falls. At first, the capital-labor ratio also falls, since the majority of the economy's capital is now of a non-frontier vintage, and it takes several periods for the ratio to recover. When the process is complete, the economy converges to a new steady state growth path and stays there until the next shock hits.

Taking such a model to the data presents a challenge given the large number of parameters that need to be estimated and the brevity of the period (1953–1995) for which the authors have data on tangible wealth, hours worked, wages, interest rates, GDP, taxes, investment, and capital goods prices. Specifications in which change occurs only in the growth rate of the technology parameter, such as the ones illustrated in Fig. 2 of their paper, do not appear to capture much of the variation in interest rates. In the end, the authors settle upon a specification with a single, exogenously imposed break point in the early 1970s. A world in which technology advances only in a punctuated manner requires capital goods prices to decline in discontinuous steps as well. Fig. 3, however, which shows quality-adjusted prices of equipment relative to consumption goods from 1947, indicates that relative equipment prices, though indeed falling more rapidly after 1971, do not resemble a single-step function.[4] And it is the abruptness of the imposed shock in the punctuated model that delivers a sharp, one time response in interest rates.

1.3. Concluding remarks

In all, Laitner and Stolyarov make an interesting contribution to the GPT and productivity literatures. Their model represents an effort to capture the richness of

[4] Krusell et al. (2000) build this relative price series for equipment from 1963 using the consumer price index to deflate the quality-adjusted estimates of producer equipment prices from Gordon (1990, Table 12.4, col.2, p.541). Since Gordon's series ends in 1983, they use VAR forecasts to extend it through 1992. The series in Fig. 3 starts with Krusell et al. and works backward, deflating Gordon's remaining estimates (1947–1962) with an index for non-durable consumption goods prices from the National Income and Product Accounts.

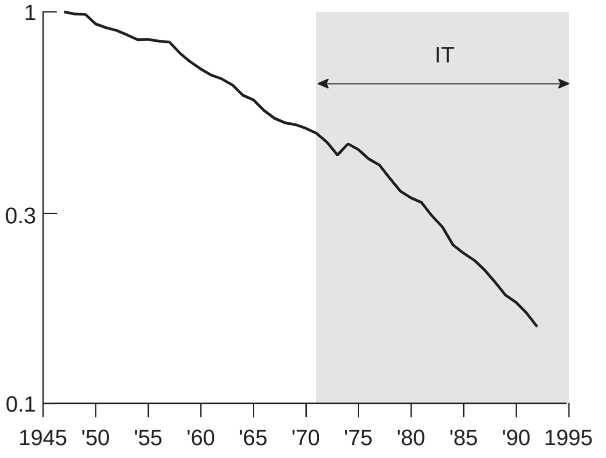

Fig. 3. The relative price of equipment, 1947–1992.

technological transformations in a tractable framework that allows for growth accounting. And despite the increased complexity, their version of the Solow model is still remarkably elegant. Questions remain, however, regarding how the model might perform with longer time series that allow for more than one technology shock, or with alternative data-driven break points, or with technology shocks that arrive more infrequently than the authors assume from their reading of history. I anxiously await the next installment.

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