NBER WORKING PAPER SERIES

THE PRE-PRODUCERS

Boyan Jovanovic

Working Paper 10771
http://www.nber.org/papers/w10771

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2004

The Pre-Producers
Boyan Jovanovic
NBER Working Paper No. 10771
September 2004
JEL No. L0, G3

ABSTRACT

Until its sales of a product materialize, a firm is a "pre-producer" in the market for that product. That firm may may be a new start-up, or it may already sell other products. Firms that do not succeed in generating sales eventually become discouraged and move on to other activities. When this fate befalls a lot of firms, as it recently did in several IT-related businesses, the industry experiences a "shakeout." In the model that I will present, during the shakeout some firms switch to flatter, safer earnings. This switch raises earnings at the time of the shakeout but lowers them in the long run, and it therefore raises earnings-price ratios. This has happened on the Nasdaq since March, 2000 when the Nasdaq shakeout began.

Boyan Jovanovic
Department of Economics
New York University
269 Mercer Street
New York, NY 10003
and NBER
bj2@nyu.edu

The *Pre*-Producers

Boyan Jovanovic*

September 6, 2004

Abstract

Until its sales of a product materialize, a firm is a "pre-producer" in the market for that product. That firm may may be a new start-up, or it may already sell other products. Firms that do not succeed in generating sales eventually become discouraged and move on to other activities. When this fate befalls a lot of firms, as it recently did in several IT-related businesses, the indistry experiences a "shakeout." In the model that I will present, during the shakeout some firms switch to flatter, safer earnings. This switch raises earnings at the time of the shakeout but lowers them in the long run, and it therefore raises earnings-price ratios. This has happened on the Nasdaq since March, 2000 when the Nasdaq shakeout began.

1 Introduction

Since March of 2000, a wave of e-commerce and computer companies have folded. Several years after their founding, many had not managed to sell anything. And at the tail end of the 19th century some 90% of the hundreds of automobile pre-producers never sold a single car – the median pre-production time was less than a year but some were at it for more than 10 years (Carroll and Hannan, 2000).

Pre-producers predominate in new industries. It is new industries, where commercial success is risky and delayed, and where market share is up for grabs, that show most volatility in stock-price indexes (Mazzucato 2002). This paper will link these facts with a simple model.

In the model, a pre-producer of a product is born when a firm starts devoting resources to that product market or diverting them from its activities in other markets. Pre-production ends when sales start coming in. The waiting time until sales start

*I thank D. Evans, M. Hannan, S. Klepper, and C. Syverson for comments on an earlier draft. Special thanks to J. Montoriol who supplied and analyzed the Spanish data, and to I. Guler for supplying and helping analyze the VC data. Thanks also to J. Prat for correcting an important error and to A. Gavazza for ably assisting on the project.. Thanks, finally, to the NSF for support.

is a random variable, drawn independently by firms from the same distribution. The main results are

1. Firms that remain pre-producers eventually become discouraged and move on to other activities – a "shakeout."

2. The shakeout is when firms opt for flatter, safer income streams. This switch raises earnings at the time of the shakeout but lowers them in the long run, and it therefore raises earnings-price ratios. This is indeed what has happened on the Nasdaq since March, 2000 when the shakeout began.

By waiting for sales to materialize, a pre-producer creates value – a form of organization capital. As the industry matures and as the product price declines, that capital gradually loses its value. The implications for stock prices depend in part on whether pre-producers are mainly new firms, or lateral entrants that own capacity in other industries. On the other hand, the mix of *de novo* and *de alio* capital has no bearing on the industry price, quantity and on the size of the shakeout.

2 Evidence

First we shall review evidence on pre-production, a period during which firms wait for their sales to materialize, and during which some firms succeed ahead of others. Section 2.1 reports evidence on this. The implications for the stock market hinge on there being lateral entry and on firms being able to re-focus their activities when faced with declining markets. Section 2.2 will report evidence on that.

2.1 Pre-production

The model dichotomizes a firm's life-cycle experience into a "start-up" and a "maturity" phase, and ignores all intermediate stages. This gets some support from several sources. In the pharmaceutical industry the fortune of a new firm is tied to whether its patented drug will be approved – the average time from a drug's first worldwide patent application to its approval by the FDA is 13 years (Dranove and Meltzer 1994). Elsewhere the lag is shorter: Carroll and Hannan (2000) report evidence on automobile and beer pre-producers where the pre-production period was closer to a year. Related evidence on time to build (Koeva 2002) and on patent-gestation lags (Pakes and Schankerman 1984) puts the lag (which in this case has a different meaning) at about 2 years.

These are estimates of average waiting times. Next I shall show evidence that waiting times differ considerably across firms.

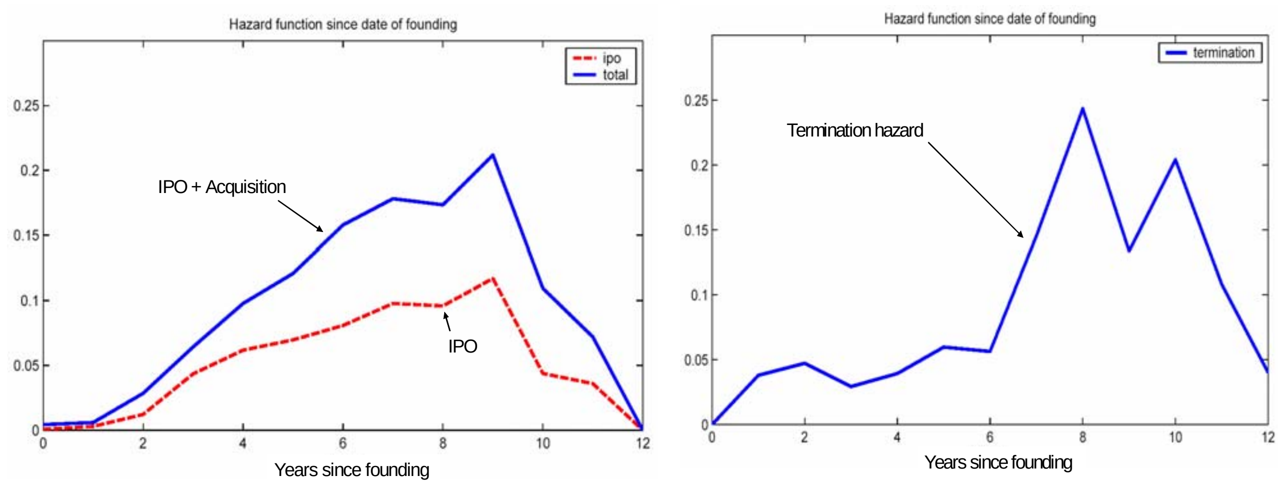

Figure 1: SUCCESS AND FAILURE HAZARDS IN DATA ANALYZED BY GULER (2002)

2.1.1 Venture-capital backed companies

The first panel of Figure 1 reports the success and failure hazards for a sample of 1355 VC held firms. The companies were founded between 1989 and 1993, and the period of coverage extends to 2001. Guler (2002) compiled the data from the VentureExpert database. A VC's goal is to unload the firm via an IPO or an acquisition; hence the solid line in the left panel represents successes from the VC's viewpoint. I interpret IPO or merger to reflect news of the firm's commercial viability; it then has a meaning similar to the revenue hazard reported in Figure 2.

Guler (2002) reports hazards in which the horizontal axis reports not calendar time, but investment rounds so that in that case "time" begins with the first investment round. The hazards look quite similar to the ones I report here. Therefore the essential properties of these hazards do not arise because firm founding is a noisy measure of when the firm really gets started. These data show the success hazard peaking between years 6 and 9, and with the termination hazard peaking between years 7 and 11.

Other, similar data provide information about a company's status at the time of VC investment in it. Gompers and Lerner (1999, table 5.2) report that in their sample the median company age was 3 years. Of these, only 53% had sales and only 7.6% were profitable. Thus it would seem that it takes the median firm about 3 years to generate sales. Kaplan and Strömberg (2003) report that about half of the investment rounds were "pre-revenue rounds," i.e., investments in firms that had no

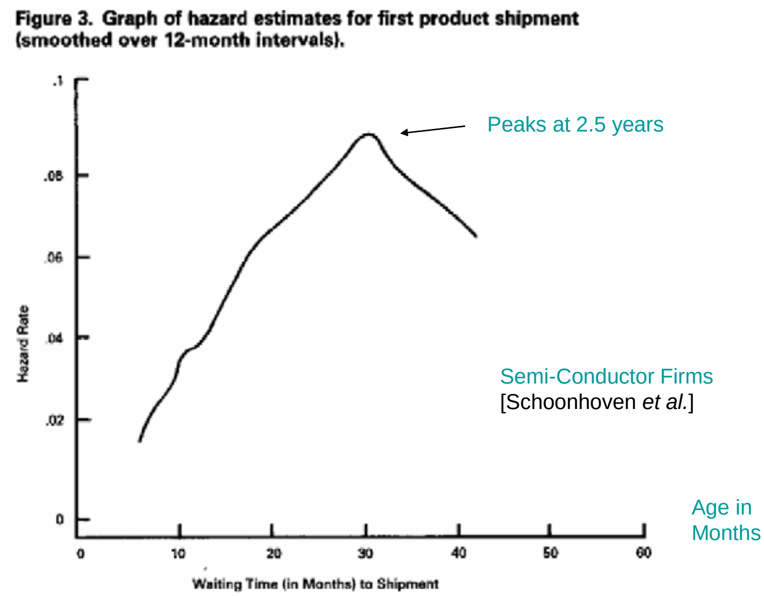

Figure 2: Schoonhoven's evidence on semi-conductor firms

sales.

2.1.2 The revenue hazard

Schoonhoven *et al.* (1990) report a bell-shaped hazard that peaks at 2.5 years. The hazard is actually a 12-month moving average of the hazards, the smoothing was needed because the sample was relatively small. The firms are 98 U.S. semi-conductor pre-producers, founded between 1978 and 1993. Of these, 89 had managed to ship their first product before the data were collected. The horizontal axis measures time in months. There is variance in the waiting times, though less than we see in the VC data.

2.1.3 Firm age and sales

Since pre-production is defined by the absence of sales, let us look at some evidence on how a firm age relates to its sales. Most work with plant-level and firm-level data from the U.S. uses employment or assets to measure firm size, e.g., Evans (1987). But pre-producers typically do own assets and employ workers – it is *sales* that they do not have.

Figure 3 presents plots for monthly sales as a function of the firm's age measured in months. The data contain the financial accounts for more than 190,000 Spanish

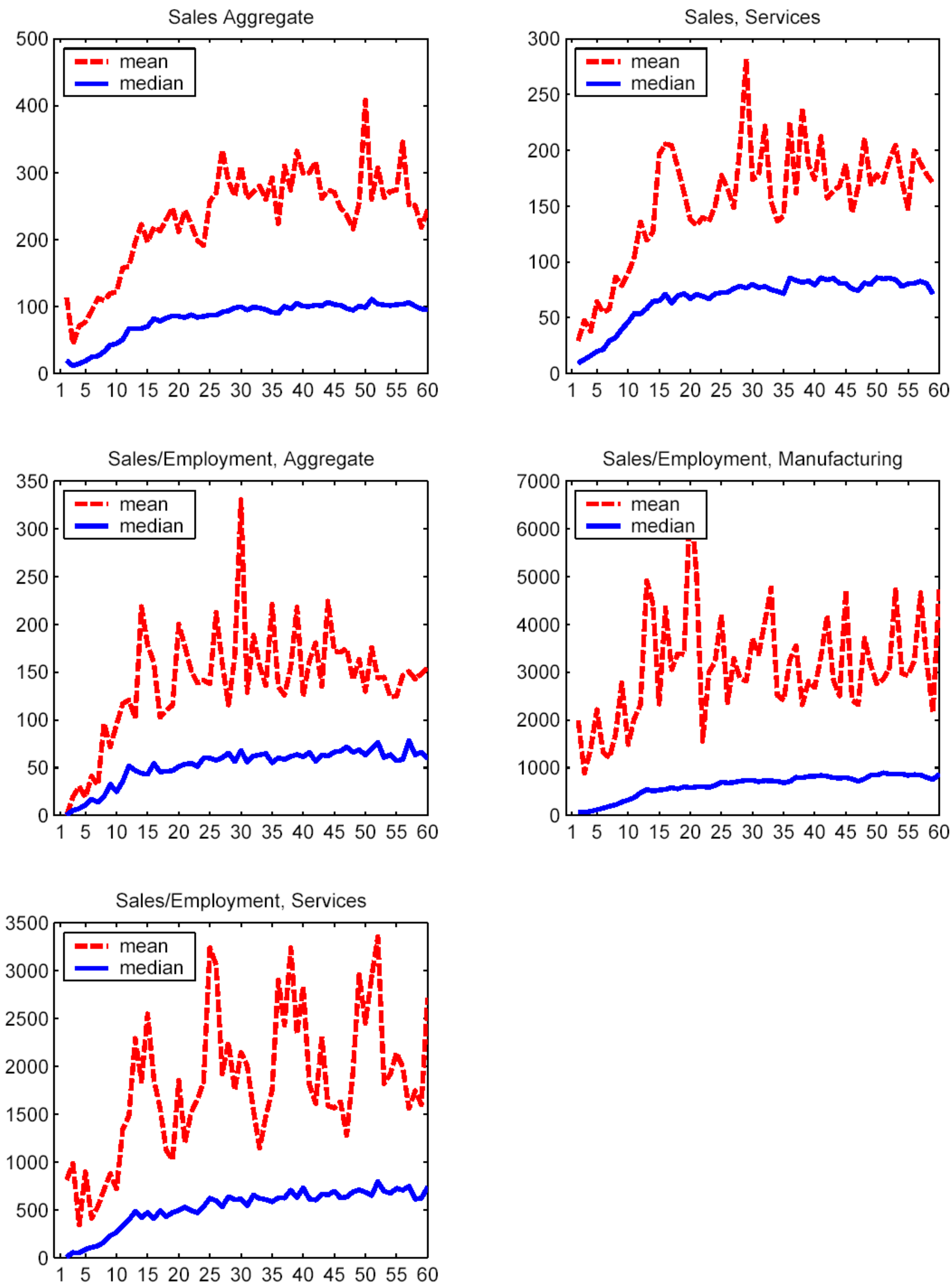

Figure 3: Monthly Sales and Sales/Employment ratio, in millions of 1995 Euros.

firms for the period 1989-2001.[1] The plots pool firms from different cohorts.

The sample excludes many pre-producers because firms must have some sales to be included in it. Therefore the median and the mean are both biased up in the early months. Yet both sets of curves show a convex portion in the first year or so, indicating the presence of an initial low-sales epoch. Figure 3 also shows that mean size exceeds median size by a factor of three or more, a symptom of heterogeneity.

2.2 Lateral entry and re-definition

In the early automobile industry, of 2197 entrants about one third were *de alio* (Carroll *et al* (1996). Some had been carriage producers (e.g., Studebaker), some steam-engine producers (e.g., Oldsmobile), or precision-metal producers (Leland and Faulconer – later Cadillac – and the Dodge Brothers). Then in the 20s, during the shakeout, many automakers switched to making bicycles. In the early TV industry, 26 percent of the entrants were radio producers (Klepper 2004, Table 2). And in the early disk-drive industry, about 75 percent of entrants were *de alio* (Khessina and Carroll, 2004).

One way in which de-alio capital enters a new industry is through merger or acquisition. Gort (1962) showed that the target is more likely to be in an expanding industry and an acquirer is more likely to be in a declining industry. Gort, Grabowski and McGuckin (1985) later refined this argument, focusing on the role of management. They argue that a management team is for various reasons indivisible, and when it experiences "slack", it may try to take over another company and manage it. A pre-production effort, when abandoned, can induce the firm to move its organizational skills to an area where it will draw higher returns.

An example of a company that has re-defined itself is IBM. Table 1 compares the distribution of revenue that IBM reported in its 10Q filing with the SEC for the second quarter of 2004 with that for the second quarter of 1994:

	2Q '94		2Q '04	
Product type	$ bil.	%	$ bil.	%
Hardware	7.7	.50	7.4	.32
Software	2.7	.18	3.5	.15
Services+Maintenance	3.9	.25	11.3	.49
Rentals & Financing	.8	.05	0.9	.04
Total	15.4	100	23.2	100

Table 1: IBM's EARNINGS IN 2004 VS. 1994

[1] The Database is *Sabe* (Sistema de análisis de balances españoles). The variables used are: Total sales (variable #727), and the total number of employees (#94). Sales were deflated bythe Deflator for Total Domestic Demand (taken from OECD's *Economic Outlook*).

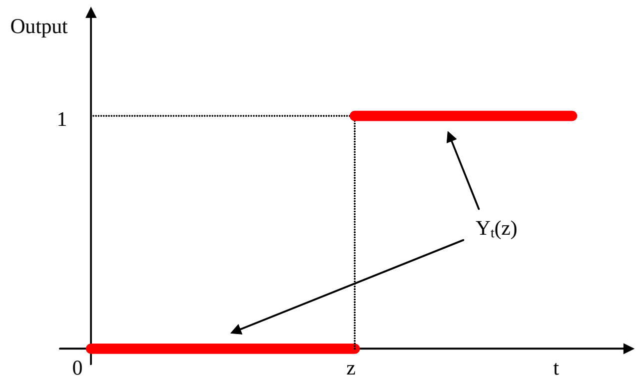

Figure 4: Type-z firm's otput as a function of its age

The computer market has operated on small margins and producers have been moving to other markets, with IBM moving to international business consulting so that it is now a service company more than a manufacturing one.

Less dramatically, Apple too is re-focusing; its 10K filing with the SEC reveals that between 2001 and 2003 its annual net sales of peripherals and other hardware rose $671 million, most of which was because of the rise in Ipod sales, and not of Apple PCs.

3 Model

Consider an industry in which a fixed inverse-demand curve $p = D(q)$. The Appendix studies the case in which $D(\cdot)$ also depends on calendar time. Firms are infinitessimal and risk neutral, and face an interest rate of r which is exogenous.

The age-productivity profile of a firm.—Conditional on its age, t, and its type, z, the firm's output is

$$Y_t(z) = \begin{cases} 0 & \text{if} \quad t < z \\ 1 & \text{if} \quad t \geq z. \end{cases}$$

It is plotted in Figure 4. We can think of it as a learning curve. It is a random function because z is a random variable.

The industry age-productivity profile.—Ex-ante, firms are the same in that each believes itself to be a random draw from the distribution $F(z)$. The realized z's are uncorrelated. There is no aggregate uncertainty, so that (until exit starts) actual output per firm is also the expected output of each firm is

$$\int_0^\infty Y_t(z)\, dF(z) = F(t)$$

and F is exogenous. In a new industry that uses a new technology, many designs and techniques may look equally promising ex-ante. The waiting times, z, differ over firms perhaps because each uses a slightly different technique. All the gains in productivity come from the "extensive margin" whereby a pre-producer becomes a producer.

Evolution of output.—Output, q, equals the number of producers. Everyone enters as a pre-producer. Let us impose a unit maximal capacity on each firm. Let k denote the number of firms, and the total potential capacity of all the pre-producers. Then if no capacity is withdrawn from the industry $k_t - q$ is the number of pre-producers at date t. Define the hazard rate of F as[2]

$$h = \frac{f}{1-F}.$$

Thus the differential equation for q is

$$\dot{q} = (k-q)\,h.$$

Since the equilibrium price in the industry cannot rise, all entry will occur at date zero.

Exit.—Alternative earnings are r per unit of capacity per unit of time.[3] They will induce some pre-producers to exit if staying in the industry offers prospects that are sufficiently bleak.

The values of firms.—It will turn out that $p_t \geq r$ for all t, so that producers never exit. Then the value of a producer is

$$V_t^* = \int_t^\infty e^{-r(s-t)} p_s ds.$$

For keep things simple, I assume physical depreciation to be zero everywhere. Then as long as $V \geq r/r = 1$, a pre-producer is happy to stay in the industry.

As we shall see, every remaining pre-producer will exit on the same date. Let T be that date. For all $t \leq T$ then, the value of a pre-producer is[4]

$$V_t = \int_t^T e^{-r(s-t)} p_s \left(\frac{F_s - F_t}{1-F_t}\right) ds + e^{-r(T-t)} \left\{ \left(\frac{F_T - F_t}{1-F_t}\right) \frac{p_T}{r} + 1 - \frac{F_T - F_t}{1-F_t} \right\}$$

[2] When no confusion is likely, I shall use subscripts to denote arguments of various functions. So instead of $F(t)$ and $p(t)$ for example, I shall write F_t and p_t.

[3] Therefore we are assuming that capital is general. If capital were purely specific, its salvage value would be zero and we would not see any exit of pre-producers. The truth is somewhere in between, but to keep things simple I shall deal only with the extreme case of general capital.

[4] This is because the value of of exit is unity, and because Bayes' rule gives

$$\Pr\{Y_s = 1 \mid Y_t = 0\} = \frac{F_s - F_t}{1-F_t}.$$

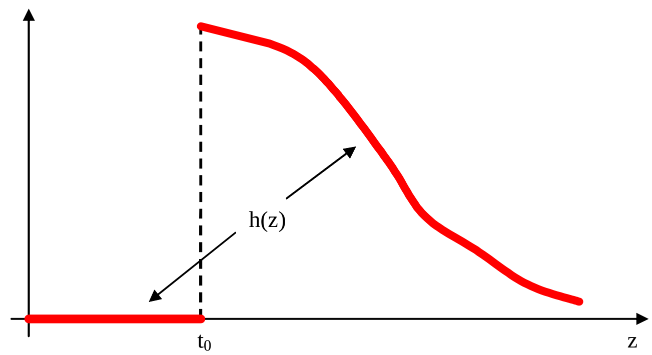

Figure 5: THE SHAPE ASSUMED FOR $h(z)$

The theoretical hazard.—The analysis simplifies if we narrow down the set of F's as follows: Let

$$F(z) = \begin{cases} 0 & \text{for } z < t_0 \\ G(z - t_0) & \text{for } z \geq t_0 \end{cases}$$

where G is a cumulative distribution with a non-increasing hazard. Then it follows that

$$h(z) = \begin{cases} 0 & \text{for } z < t_0 \\ \frac{g(z-t_0)}{1-G(z-t_0)} & \text{for } z \geq t_0, \end{cases}$$

as shown in Figure 5. To avoid tedious references to corners, let us assume that $G_t < 1$ for all $t < \infty$ so that $h(z) > 0$ for all z. The shape assumed for h is a compromise between the reality of Figures 1 and 2, and tractability. The Appendix The Appendix studies the case in which F is general.

Equilibrium.—With F thus restricted, the nature of equilibrium is easily deduced. All pre-producers, k of them, enter at date zero. Output then equals kF_t, and p_t then equals $D(kF_t)$ for as long as no exit takes place. After date t_0, the prospects of pre-producers get steadily dimmer because both p_t and h_t are declining. If any exit does take place, it all occurs at a single date, T, when the remaining pre-producers all exit. Output and price stabilize and there are no further dynamics.

For that to be true, however, two other conditions must be met:

1. While the value of entry is zero at date zero,

$$V_0 = \max_{T \geq 0} \left\{ \int_0^T e^{-rs} p_s F_s ds + e^{-rT} \left(F_T \frac{p_T}{r} + 1 - F_T \right) \right\} = 1, \quad (1)$$

the value of entry must thereafter be negative:

$$\max_{T \geq t} \left\{ \int_t^T e^{-r(s-t)} p_s F_{s-t} ds + e^{-r(T-t)} \left(F_{T-t} \frac{p_T}{r} + 1 - F_{T-t} \right) \right\} \leq 1.$$

2. While pre-producers are indifferent between exiting at T and remaining in the industry,
$$V_T = 1, \tag{2}$$
They must strictly prefer to remain in the industry before that, i.e., $V_t > 1$ for $t \in (0, T)$.

In fact, both conditions are met. The first is met because (i) the transition from pre-production to production depends on the firm's own age $s - t$ alone, and because (ii) the equilibrium price declines with time, so that nothing is gained by delaying entry. The second is met because – as I shall show below – the value of pre-producers rises at the rate r until date t_0 after which time it monotonically declines.

Analysis.—The unknowns are k, and T. Denote the solution in (1) for V_0 by
$$V_0 = V_0 \left(k\right).$$
Since $p_t = D\left(kF_t\right)$, $V_0'\left(k\right) \leq 0$. The corner conditions will be explained diagrammatically below. The first-order condition for a maximum in (1) with respect to T is that
$$p_T F_T - r\left(F_T \frac{p_T}{r} + 1 - F_T\right) + \left(\frac{p_T}{r} - 1\right) f_T = 0,$$
i.e., that
$$\left(\frac{p_T}{r} - 1\right) h_T = r. \tag{3}$$
Condition (3) is derived on the presumption that $\dot{p}_T = 0$, which must be true if every other pre-producer exits exactly at T in which case $p_t = p_T$ for all $t \geq T$. Is says that foregone earnings must equal the expected discounted gains from waiting another instant. This gives us a function p_T in terms of T alone:
$$p_T = \left(1 + \frac{r}{h_T}\right) r. \tag{4}$$
Again, the corner conditions will follow. From (4) we see that in the limit the industry price falls to a level that includes a markup that compensates the pre-producers for staying in the race and foregoing the income r.

We also know, however, that since no exit takes place before T,
$$p_T = D\left(kF_T\right). \tag{5}$$
Combining these two conditions leads to a restriction on k and T:
$$D\left(kF_T\right) = \left(1 + \frac{r}{h_T}\right) r. \tag{6}$$

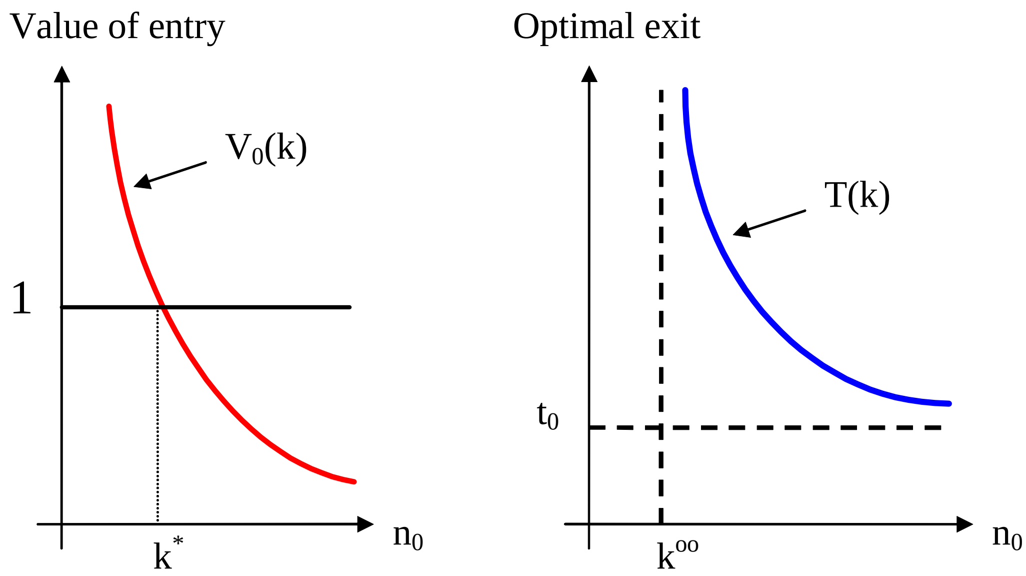

Figure 6: Restrictions implied by (1) and (2).

The second restriction is (1), which we can write as

$$\int_0^T e^{-rs} D(kF_s) F_s ds + e^{-rT} \left(F_T \frac{D(kF_T)}{r} + 1 - F_T \right) = 1. \tag{7}$$

Let

$$T = T(k)$$

solve (6) for T. This is the optimal exit relation that satisfies $T'(k) < 0$. The functions $V_0(k)$ and $T(k)$ are drawn in Figure 6. The value k^* is the equilibrium number of entrants, while k^∞ solves

$$\int_0^\infty e^{-rt} D(kF_t) F_t dt = 1$$

for k. This is the number of firms that would just break even if they had to remain in the industry for ever.

Conditions under which exit occurs.—When t_0 is large or when demand is highly inelastic, it will turn out that equilibrium will have so few firms entering that price will never decline so much that any of them will ever wish to exit.

Lemma 1 *Exit occurs if and only if*

$$k^\infty < k^*.$$

Proof. This proof refers to the second panel in Figure 6. (i) **If**: Since k^* lies to the right of k^∞, we have $T(k^*) < \infty$. (ii) **Only if**: Now k^* is to the left of k^∞ which means that $T(k^*) = \infty$. ■

Proposition 1 *exit takes place if and only if*

$$D(k^\infty) < \left(1 + \frac{r}{\inf_{t>t_0} h_t}\right) r, \tag{8}$$

Proof. (i) **Only if**: By construction, $k = k^\infty$ and $T = \infty$ is an equilibrium as long as $D(k^\infty F_t) \geq \left(1 + \frac{r}{h_t}\right) r$ for all t. The latter is guaranteed is (8) fails. (ii) **If**: When (8) holds, $k = k^\infty$ and $T = \infty$ is not an equilibrium because $D(k^\infty F_t) < \left(1 + \frac{r}{h_t}\right) r$ for some finite t. Therefore $V_0(k^\infty) > 1$ which, from the left panel in Figure 6 implies that $k^* > k^\infty$. But then the right panel implies that $T(k^*) < \infty$. ■

The age-sales relation.—Looking back at Figure 3, what does the model imply for the two lines? The dashed line is mean sales. Expected sales conditional on firm age are zero for $t < t_0$, followed by

$$E(\text{sales} \mid \text{age} = t) = \begin{cases} F_t D(kF_t) & \text{for } t \in [t_0, T), \\ F_T D(kF_T) + (1 - F_T) r & \text{for } t \geq T. \end{cases}$$

If demand is elastic, a firm's expected sales rise gradually as of date t_0, then jump further up at date T, and then remain constant. If demand is *in*elastic, expected sales jump at date t_0, then gradually decline until date T, and then again jump up at date T. On the other hand, median sales should be zero until the date at which $F_t = 1/2$, and they then should equal $D(kF_t)$ and therefore be declining. Here the model is handicapped by the sample which excludes firms that have no sales. If such firms were included, the median would have been closer to zero in the early months. The model does, at least, generate the S shape for the two lines which seems to be present in all the five panels of Figure 3.

4 Earnings and the value of capital

De alio capital matters for stock prices in a new industry. It is also important in fact. Let K be the capacity that the firms in question hold in other industries where it draws a return of r. Moreover, let δ denote the fraction of k that is introduced by *de alio* entrants, and $1 - \delta$ the fraction held by *de novo* entrants. In what follows I suppose that (8) fails so that $T < \infty$. In that case $(1 - F_T) k$ units of capital are withdrawn to other uses, but a fraction δ of this capacity remains in the hands of listed firms that convert it to other uses.

Earnings.—Earnings are

$$E_t \equiv \begin{cases} rK + p_t q_t & \text{for } t < T, \\ rK + p_T q_T + \delta r k (1 - F_T) & \text{for } t \geq T. \end{cases}$$

If demand is elastic, dividends rise continuously until date T when they jump *up*. The nominal share of IT has risen from under two percent in 1980 to over six percent today, while the price of IT-related products have fallen rapidly. Therefore the demand is elastic and the IT-counterpart of pq has risen steadily. In what follows I shall therefore assume that demand is elastic.[5]

Value of assets.—Since $V_T = 1$ and since $V_T^* = p_T/r$, the total value of all assets of the firms is

$$M_t \equiv \begin{cases} K + k\left(F_t V_t^* + [1 - F_t]\, V_t\right) & \text{for } t < T, \\ K + k\left(F_T \frac{p_T}{r} + \delta\,[1 - F_T]\right) & \text{for } t \geq T. \end{cases}$$

It too should be rising but, in contrast to earnings, M cap has a *negative* jump at T, as the de-listing firms remove $(1-\delta)(1-F_T)\,k$ capital value from the total owned by.

The ratio E_t/M_t.—Since earnings rise monotonically to their eventual plateau of $rK + p_T q_T + \delta rk\,(1 - F_T)$, and since market value anticipates this, the ratio of earnings to market cap should rise steadily from zero to a high at date T. At date T the ratio should jump to its highest level and remain there.

Measurement.—To illustrate how the model can be applied, let us imagine the firms in the Nasdaq as all competing in one market, and call that the market for "IT" for short. Then k is the capital they devote to IT, and K the capital they devote to other, stable markets in which they draw earnings of rK. This grossly simplifies things, in that (i) the activities of the Nasdaq are quite diverse and (ii) many Nasdaq firms compete with firms listed on the NYSE – e.g., IBM which we mentioned in Section 2.2. The fact is, however, that most of the Nasdaq's subindexes have moved together over the past decade, and that they have moved much more than the NYSE index. I shall measure M as the stock-market capitalization plus the market value of debt of the Nasdaq firms, deflated by the CPI, and I shall refer to M as "capitalization" for short. This will give us the real value of the capital stock owned by stock holders and the debt holders of firms traded on the Nasdaq. Earnings, E_t, are also deflated by the CPI.[6] The results are plotted in Figure 7. The left panel shows that capitalization fell between end-1999 and end-2000, whereas earnings rose substantially. The right-hand panel shows that the ratio has risen substantially since 1999.

Stock-price indexes.—The model has no aggregate shocks, and so it predicts that the return on the market portfolio must equal r. Since producers' dividends are p_t,

[5] Evidence from Chun and Mun (2004) has it that the elasticity of demand is $0.5 - 0.9$ but these results are at the three-digit industry level. They attribute to industry-output expansion what, for our purposes, is a movement along a demand curve.

[6] The data are from the CRSP/COMPUSTAT Merged Database. In terms of the subnumbers, the construction of the variables is as follows:

M = (24)x(25) + (9) + (34) and E = (53)x(54)

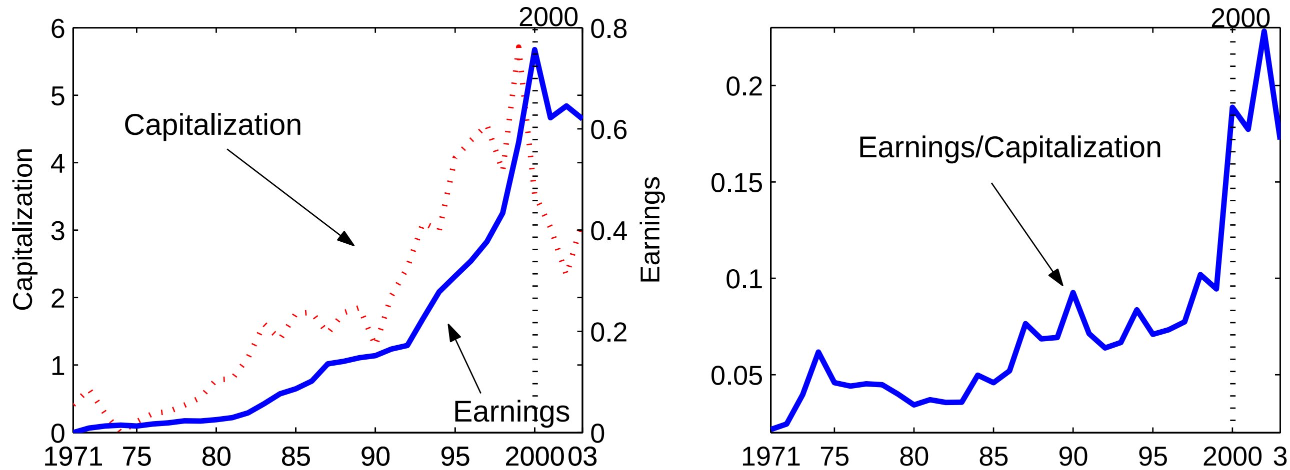

Figure 7: M_t AND E_t (LEFT PANEL) AND E_t/M_t (RIGHT PANEL).

arbitrage requires that capital gains of producers satisfy

$$\frac{\dot{V}^*}{V^*} = r - \frac{p}{V^*} \leq 0.$$

For $t \in [t_0, T)$, the inequality is strict because $\dot{p}_t < 0$ implies $V_t^* < p_t/r$. As for pre-producers, let us assume that in the event of exit, shareholders can recover the full value of the pre-producer's assets, i.e., 1. Then V_t is also the pre-producer's market value. A pre-producer pays no dividends. Arbitrage requires that until date T,

$$\frac{\dot{V}}{V} = r - \left(\frac{V^* - V}{V}\right) h.$$

The model implies that after the shakeout, when dividends rise, stock-price appreciation should fall. While it cannot explain the abnormally high cumulative returns on the Nasdaq in the late 90's and the low cumulative returns since 2000, the model explains why there was more appreciation before 2000 and less since.

5 Example: A constant hazard

Suppose that $F_t = 0$ for $t < t_0$ and that

$$F_t = 1 - e^{-\lambda(t-t_0)} \text{ for } t \geq t_0 \quad \text{and} \quad D(q) = \frac{A}{q}.$$

Since $D(kF_t) F_t = \frac{A}{k}$, k^∞ solves $\frac{A}{k} \int_{t_0}^{\infty} e^{-rt} dt = 1$, so that $k^\infty = e^{-rt_0} \frac{A}{r}$. Therefore $D(k^\infty) = re^{rt_0}$(8) is equivalent to

$$e^{rt_0} < 1 + \frac{r}{\lambda}, \tag{9}$$

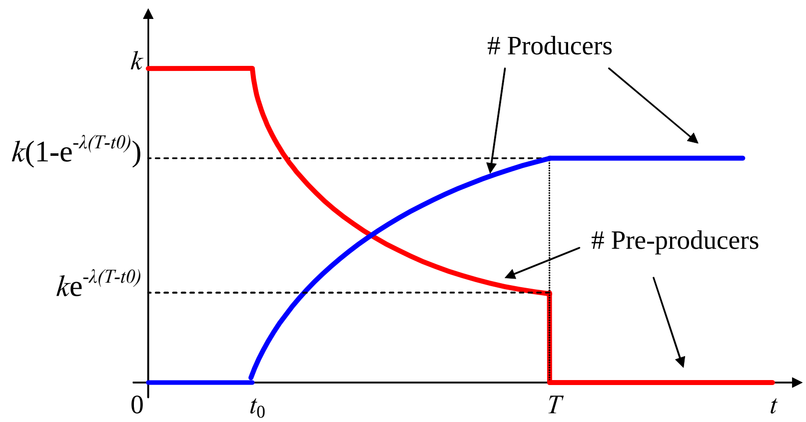

Figure 8: PRE-PRODUCERS AND PRODUCERS IN THE CONSTANT-HAZARD CASE

which must be met for there at exist exit at some date T.

For $t_0 < t < T$, $q_t = k\left(1 - e^{-\lambda(t-t_0)}\right)$, so that (6) now reads

$$p_T = \frac{A}{k\left(1 - e^{-\lambda(T-t_0)}\right)} = \left(1 + \frac{r}{\lambda}\right)r,$$

The second restriction is (7), which now reads

$$\frac{A}{k}\int_{t_0}^{T} e^{-rs}ds + e^{-rT}\left(\frac{A}{rk} + e^{-\lambda(T-t_0)}\right) = 1.$$

These are two equations in the unknowns (k, T). The time path of producers and pre-producers is shown in the left panel of Figure 8, and the price path in the right panel.The rising solid line is the number of producers and also the relation between age and a firm's expected output until date T. A firm's expected sales, however, are zero before t_0, and after that they are $p_t F_t = \frac{A}{k}$, a constant, until date T when they jump up to $\frac{A}{k} + \left(1 - F^{-\lambda(T-t_0)}\right)r$. This is the counterpart of the relations plotted in Figure 3.

Aggregate earnings are zero for $t < t_0$, A for $t \in [t_0, T)$, and $A + ke^{-\lambda(T-t_0)}r$ thereafter. Now let us simulate the example's implications for the series plotted in Figure 7. Because demand is unit elastic earnings are constant at $A = 10$. The parameters satisfy (9) and they were chosen so as to exaggerate the impact of the shakeout at T on E. The impact is large when a lot of pre-producers are still left at T so that the shakeout is large. The left panel shows capitalization rising until the shakeout date of $T = 6$ and that, also as in the data, capitalization drops and earnings rise at that date.

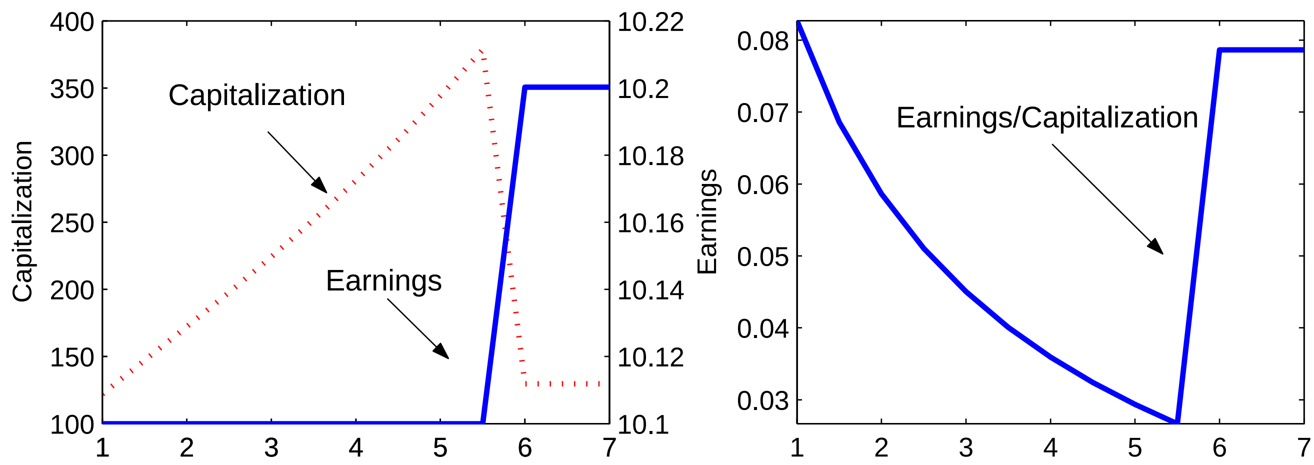

Figure 9: SIMULATION OF E_t, M_t AND E_t/M_t WITH $A = 10$, $\lambda = .02$, $r = .1$, $t_0 = 1$, $K = 1$ AND $\delta = .05$.

6 Literature review

In the model a firm has the option to engage in other activities should its activities in the industry at hand turn out to be a failure. The value of that outside option is unity. The firm therefore likes uncertainty about future profitability in the industry. As in Pastor and Veronesi (2004), find that uncertainty was especially high in the late 1990s. They calibrate a stock valuation model that includes this uncertainty, and show that the uncertainty needed to match the observed Nasdaq valuations at their peak is high but plausible. My model puts a different structure on the uncertainty, and focuses on the transition from pre-production to production, thereby pointing to a different set of facts – facts we reviewed in Section 2. Moreover, I focus on industry equilibrium and industry life cycle so that a firm's dividends depend on industry-wide forces.

A form of pre-production occurs in the Mortensen-Pissarides type of model in which an unfilled vacancy can be viewed as a pre-producing firm. Pissarides (2000, ch. 1.7) shows that after a favorable shock, many vacancies come in. But then the falling u/v ratio plays the role that falling p_t does here, and if exit of a vacancy were allowed, one would expect to see it: Unless it manages to find a worker early, the vacant firm will get discouraged and "exit." That model has the advantage of endogenizing the hazard rate through movements in vacancies and unemployment.

The model relates to the patent-race literature (Loury 1980) except that instead of winner-take-all, I impose market sharing by limiting the capacity of firms, so that even the latecomers get revenue. These models also endogenize the hazard via the patent racer's research decision.

The model treats the length of the pre-production period as exogenous. Jovanovic and Rousseau (2001) and Pastor and Veronesi (forthcoming) endogenize the timing of when production begins. These papers try to explain when IPOs occur and why they bunch.

The parameter z reveals itself to pre-producers in much the same way as the firm's efficiency revealed itself to firms in the model in Jovanovic (1982). In that model, the closest thing to pre-producers are the low-output firms which have unusually high production costs. Jovanovic and MacDonald (1994) have a pre-production period and a constant production hazard; their main focus is the shakeout in the tire industry in the 1920s.

7 Conclusion

This paper has explored the role that pre-production can play in the life cycle behavior of an industry's output, product price, and the market valuations of its producers. We have seen that the model explains some features of the Nasdaq over the past three decades. A part of the price run-up could have been caused by the prospect of receiving dividends later, after the pre-production period. The rise in earnings that was, in 2000, accompanied by a fall in capitalization is partly explained by firms switching to flatter and safer earnings streams.

The results should be of more general interest. The paper shows how a particular form of organization capital should be valued. Our economic world is becoming more Schumpeterian. Product lifetimes are now shorter and firms must constantly refocus or be forced out by new firms which, when we first encounter them, are pre-producers.

References

[1] Carroll, Glenn and T. Michael Hannan. *The Demography of Organizations and Industries*. Princeton, N.J.: Princeton University Press. 2000.

[2] Carroll; Glenn, Lyda Bigelow; Marc-David Seidel and Lucia Tsai. "The Fates of De Novo and De Alio Producers in the American Automobile Industry 1885-1981." *Strategic Management Journal*, Vol. 17, Special Issue: Evolutionary Perspectives on Strategy. (Summer, 1996), pp. 117-137.

[3] Dranove, David, and David Meltzer. "Do Important Drugs Reach the Market Sooner?" *RAND Journal of Economics* 25, no. 3. (Autumn, 1994): 402-423.

[4] Evans, David S. "Tests of Alternative Theories of Firm Growth." *Journal of Political Economy*, Vol. 95, No. 4. (Aug., 1987), pp. 657-674.

[5] Gompers, Paul and Josh Lerner. *The Venture Capital Cycle*. Cambridge, MA: MIT Press, 1999.

[6] Gort, Michael, *Diversification and Integration in American Industry* NBER, Princeton, NJ: Princeton University Press, 1962.

[7] Gort, Michael, Henry Grabowski, Robert McGuckin, "Organization Capital and the Choice Between Specialization and Diversification," *Managerial and Decision Economics* 6, no. 1 (1985): 2-10.

[8] Guler, Isin. "An Empirical Examination of Aggregate Patterns in U.S. Venture-Capital Decision Making" (Sept. 2002).

[9] Jovanovic, Boyan. "Selection and the Evolution of Industry." *Econometrica* 50, no. 3 (May, 1982): 649-670.

[10] Jovanovic, Boyan and Robert Rosenthal. "Anonymous Sequential Games." *Journal of Mathematical Economics* 17 (1988): 77-88.

[11] Jovanovic, Boyan, and Glenn M. MacDonald. "The Life Cycle of a Competitive Industry." *Journal of Political Economy* 102, no. 2 (April 1994): 322-347.

[12] Jovanovic, Boyan, and Peter L. Rousseau. "Why Wait? A Century of Life Before IPO." *American Economic Review* (Papers and Proceedings) 91, no. 2 (May 2001): 336-341.

[13] Kaplan, Steven and Per Strömberg. "Financial Theory Meets the Real World: An Empirical Analysis of Venture Capital Contracts." *Review of Economic Studies* 70(2) no. 243 (April 2003): 281-316.

[14] Khessina, Olga, and Glenn Carroll. "Product Dynamics of De Novo and De Alio Firms in the Worldwide Optical Disk Drive Industry, 1983-1999." Stanford University, February 2004.

[15] Klepper, Steven. "The Geography of Organizational Knowledge." February 2004.

[16] Koeva, Petya. "Facts about Time to Build." IMF WP/00/138 August 2000.

[17] Mazzucato, Mariana. "The PC Industry: New Economy or Early Life-Cycle?" *Review of Economic Dynamics* 5, no. 2, pages (April 2002): 318-345

[18] Pakes, Ariel, and Mark Schankerman. "The Rate of Obsolescence of Knowledge, Research Gestation Lags, and the Private Rate of Return to Research Resources." *R&D Patents & Productivity*, edited by Zvi Griliches, Chicago: University of Chicago Press, 1984.

[19] Pastor, Lubos, and Pietro Veronesi. "Rational IPO Waves." *Journal of Finance*, forthcoming.

[20] Pastor, Lubos and Pietro Veronesi. "Was there a Nasdaq Bubble in the Late 90's?" NBER wp #10581 (June 2004).

[21] Pissarides, Christopher. *Equilibrium Unemployment Theory*, 2nd ed., Cambridge, MA: MIT Press, 2000.

[22] Schoonhoven, Claudia, Kathleen Eisenhardt and Katherine Lyman. "Speeding Products to Market: Waiting Time to First Product Introduction in New Firms. *Administrative Science Quarterly* 35, no. 1 (March 1990): 177-207.

8 Appendix: Existence of equilibrium in the general case

Here I allow for a general F and for a time-varying $D(\cdot)$. Time is discrete for technical reasons. Let $p = D_t(q)$ where D is continuous and uniformly bounded. Let F be a CDF over the positive integers. Let N be the measure of all firms. I shall assume that N is large enough that is ever all were to enter the industry at hand, the present value of entry would be negative. I shall be more specific below.

States and actions.—The firm's state is $s = (\sigma, \alpha)$, where σ is its production status ($\sigma = 1$ for firms outside the industry, $= 2$ for pre-producers, $= 3$ for producers), and where α is its age, measured as the time elapsed since the firm entered the industry. This variable is normalized to -1 for firms for which $\sigma = 1$ in the previous period. Calendar time $t \in I_+$ we shall keep track of separately. The individual-firm's state space then is $S = \{\{1, 2, 3\} \times I_+\}$. The action $a = 1$ means that the firm will spend the next period outside the industry, and $a = 2$ means it will spend it in the industry. Thus the set of actions is the pair $A = \{1, 2\}$.

Payoffs.—Let M_B denote the set of Borel measures over the generic set B. The population distribution over states and actions will be denoted by $\tau_t \in M_{S\times A}$. A firm can influence its state only in the next period. Since a state transition does not entail a direct cost, the firm's payoff, u_t depends only on (s, τ_t). Specifically, $q_t = \int F(\alpha)\, d\tau_t$, and so the payoffs are:[7]

$$\left.\begin{array}{r} u_t(1, \tau_t) = \frac{r}{1+r} \\ u_t(2, \tau_t) = 0 \end{array}\right\} \text{ for all } (\tau, t), \quad \text{and} \quad u_t(3, \tau_t) = D_t\left(\int F(\alpha)\, d\tau_t\right). \tag{10}$$

Individual-firm state transitions.—This is a map from states and actions into measures over states $G : S \times A \to M_S$. I shall describe $G(\cdot; s, a)$ only in words.[8] (i)

[7] In discrete time, the present value of $r/(1+r)$ is 1. This ensures that Tobin's Q remains at unity.

[8] In Jovanovic and Rosenthal (1988), G could depend directly on τ. In the present model, the states and actions of other players do not affect a firm's transition among states.

Firms in the industry: If a α-aged firm with $\sigma = 2$ plays $a = 2$, it transits to $\sigma = 3$ with probability $(F_{\alpha+1} - F_\alpha) / (1 - F_\alpha)$, and its age becomes $\alpha + 1$. If, instead, it plays $a = 1$, its σ becomes unity. Re-entry is allowed, but as a newborn with $\alpha = 0$. Thus the set of feasible actions is the same for all players.[9] *(ii) Firms out of the industry*: A firm with $\sigma = 1$ stays there with probability 1 if it plays $a = 1$, and enters the industry with probability 1 if it plays $a = 2$.

Aggregate transitions.—The aggregate state is the pair (t, μ), where $\mu \in M_S$. Then

$$\mu_{t+1}(\cdot) = \int G(\cdot; s, a)\, d\tau_t$$

Bellman equation.—Let $\tau \in M^\infty_{S\times A}$ be the infinite sequence $(\tau_t)_0^\infty$. Firms know τ and take it as given – they have perfect foresight about the aggregates. The Bellman equation is

$$v_t(s, \tau) = \max_{a\in A}\left\{u_t(s, \tau_t) + \frac{1}{1+r}\int v_{t+1}(s', \tau)\, G(ds'; s, a)\right\} \tag{11}$$

Let $\tau_{t,S}$ denote the marginal of τ_t over S.

Definition of equilibrium.—Given the initial condition μ_0, $\tau \in M^\infty_{S\times A}$ is an equilibrium if

$$\tau_{0,S} = \mu_0, \quad \text{and} \quad \tau_{t+1,S} = \int G(\cdot; s, a)\, d\tau_t \text{ for } t = 0, 1, ..., \tag{12}$$

and if for all t and all $\tilde{a} \in A$,

$$\tau_t\left(\left\{\begin{array}{cc} (s,a) \mid & u_t(s,\tau_t) + \frac{1}{1+r}\int v_{t+1}(s',\tau)\, G(ds'; s, a) \\ & \geq u_t(s,\tau_t) + \frac{1}{1+r}\int v_{t+1}(s',\tau)\, G(ds'; s, \tilde{a}) \end{array}\right\}\right) = N. \tag{13}$$

Condition (12) states that the transitions hold, and condition (13) states that all firms act optimally except possibly a set of firms of measure zero.

Existence.—G is continuous and does not depend on τ. Put the topology of weak convergence on τ_t. In this topology M_S and $M_{S\times A}$ are compact and, since $D(.)$ is continuous, u is continuous. The assumptions underlying Theorem 1 of Jovanovic and Rosenthal (1988) hold and equilibrium exists.

Characterization.—Let us discuss the model informally in terms of this abstract notation. The body of the paper takes the initial condition $\mu_0(1, -1) = N$. I.e., all firms start in the "other" sector. *Entry* at date t is just the number of firms that will next period be in the state $\{2, 0\}$,

$$\int_S G(\{2,0\}; s, a)\, d\tau_t = \tau_t(\{1, -1, 2\})$$

[9] Jovanovic and Rosenthal (1988) had additional generality that we do not need here.

which, given the restrictions on the feasibility of the transitions is the number of firms that were in state $\sigma = 1$ and $\alpha = -1$ that took the action $a = 2$. *Exit* at date t is the number of firms that will at $t+1$ be in the state $\{1, -1\}$ that in the previous period were in the state $\{2, \alpha\}$ for some $\alpha \geq 0$ and played $\alpha = 2$; i.e.,

$$\int_S G\left(\{1, -1\}; s, a\right) d\tau_t = \sum_{\alpha=0}^{t-1} \tau_t\left(\{1, \alpha, 2\}\right)$$

Since N is large, some firms always remain in the "other" sector, where they derive the lifetime payoff

$$v_t\left(1, \tau\right) = 1 \tag{14}$$

for all (τ, t). Then (14) and (13) imply that the value of entry

$$\frac{r}{1+r} + \frac{1}{1+r} v_{t+1}\left(2, 0\right) \leq 1.$$

If demand increases with t, not all the entry necessarily happens at $t = 0$ any longer. The entry set is

$$E = \left\{ t \in I_+ \mid \frac{r}{1+r} + \frac{1}{1+r} v_{t+1}\left(2, 0\right) = 1 \right\},$$

and since $u_t\left(2, \tau_t\right) = 0$, the exit set is

$$X = \left\{ t \in I_+ \mid v_{t+1}\left(2, 0\right) \leq v_{t+1}\left(1, -1\right) \right\}.$$