Founders and CEO turnover in Science-Based Business

Serguey Braguinsky, Yuji Honjo, Sadao Nagaoka, and Kenta Nakamura*

Abstract

We present a parsimonious model of CEO turnover in science-based business, where ideas initially produced by researchers with scientific knowledge capital may be developed by high-ability entrepreneurs. Startups continuously managed by founders coexist in equilibrium with startups that experience CEO turnover. The model predicts that startups managed by non-founder CEOs would have higher values than startups managed by their founders, and that better functioning of the market for entrepreneurial talent should result in more entrepreneurial turnover in equilibrium which in its turn leads to more ideas being commercialized and higher values of startups. We probe the implications of the model using a unique dataset from the survey of a representative sample of biotechnology startups in Japan and we find them to be broadly supported in the data.

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Individual-specific knowledge capital is a critical resource in science-based business (e.g., Zucker, Darby and Brewer [1998], Zingales [2000]). But to make a success, even a good idea must be implemented by an agent with high-level entrepreneurial talent (Kaplan, Sensoy, and Stromberg [2009], Braguinsky, Klepper, and Ohyama [2010]). Scientists often do not possess such a talent and/or are distracted by other interests, making them in general unlikely candidates to carry out the idea to commercial implementation (Aghion, Dewatripoint and Stein [2008]). As a result, what has been aptly called “the founder’s dilemma” (Wasserman [2008]) – whether the founder ought to continue running the business or to relinquish control – is especially strongly pronounced in science-based business.

Figure 1.

CEO turnover and capital in 347 biotechnology startups in Japan (ratio scale)

Figure 1 presents the relationship between the turnover from founders to non-founder CEOs and capital raised from a representative survey of startups in the biotechnology industry in
Japan (see Section III below). Startups where founders relinquished control were able to raise initially more capital than the startups where founders continued to run the show, and increased their advantage even more over time. Needless to say, more capital raised is one of the most important measures of success in the biotechnology industry where it often takes 10 or more years to generate revenues and profits (Pisano [2010]). Nevertheless, the fraction of businesses where founders (mostly academic researchers) were replaced by new CEOs is surprisingly low, at just 37 percent. Thus, there appears to be a puzzle – if entrepreneurial turnover is associated with better outcomes, why do so few businesses experience this turnover?

It is possible that the heart of the matter lies in the very nature of science-based business. In the case of biotechnology, “the growth and location of intellectual human capital was the principal determinant of the growth and location of the industry.” (Zucker et al. [1998], p. 302) Some researchers have therefore questioned whether the traditional concept of a business firm applies at all to science-based business (Zingales [2000], Pisano [2010]).

Accumulated empirical evidence indicates, however, that this may not be the case. Kaplan, Sensoy and Stromberg [2009] find that successful implementation of unchanging core ideas coming from basic science nevertheless involved high turnover rates among CEOs in the sample of venture capital-backed startups. That is how things appear to be in Figure 1 above (see also the data presented below in Section III). Gans, Hsu, and Stern [2002] argue that in the biotechnology industry, innovators earn returns not by pursuing their businesses independently but by acting as upstream “suppliers” of technology. Gittelman and Kogut [2003] find negative correlation between important scientific papers and high-impact innovations.
In this paper we build a simple model aimed at parsimoniously explaining the above-mentioned puzzle. In line with the literature on science-based business, the input from basic research is a “critical resource” in the sense that an innovative startup is not possible without it. There is also another critical resource, which we call “entrepreneurial ability,” but which can be interpreted broadly as including knowledge of the market and experience doing business in a given industry. This resource has repeatedly been found to be the most important predictor of success in high-tech industries of the past (e.g., Klepper [2002]), and we argue that in this sense, science-based business is no different. The expected value of a startup is the product of two factors, the inputs from basic research and entrepreneurial ability.

In the model, science-based startups that experience CEO turnover have on average higher values than those that don’t. Nevertheless, such higher-valued startups coexist in equilibrium with startups of lower value that are continuously managed by their founders. The key role is played by the variable representing costs involved in evaluating the business potential of the idea before developing it. If pre-development evaluation costs are very high, the only equilibrium is the one in which all founders develop their own projects of uncertain quality, and startup values are low. Lower evaluation costs produce the equilibrium where founders with low and high entrepreneurial ability choose to evaluate their projects, while founders with intermediate ability run their businesses without evaluation. Among founders that pay the evaluation costs, high-ability entrepreneurs whose projects turn out to be useless are hired to develop good projects for startups founded by entrepreneurs of low ability. There might also be more startups in this equilibrium than in the one without evaluation.
The variable representing pre-development evaluation costs is parsimonious in that it can accommodate a variety of explanations advanced in the literature. For example, ideas may require outside expertise to determine their commercial viability. Such outside expertise is likely to be costly, and better functioning of capital markets and especially access to venture capital will reduce these costs, leading to more entrepreneurial turnover and higher startup values in equilibrium. Using outside expertise may also entail the risk of the idea being stolen (Hellmann and Perotti [2010]). In such a case, evaluation costs can be reduced and entrepreneurial turnover increased by a better functioning of the “market for ideas” (Gans et al. [2002]) and by the establishment of TLO offices and other support measures to help university-based entrepreneurship (Jensen and Thursby [2001]).

Wasserman [2008], building upon formidable previous literature (e.g., Hamilton [2000], Moscowitz and Vissing-Jorgensen [2002]), argues that profit-generating turnover from founders to better entrepreneurs may be hampered by the extra utility component of retaining control. Our pre-development evaluation cost parameter can also be interpreted as the compensating differential. For example, if the average project is destined to be not viable (as is likely to be the case in science-based business), a founder may enjoy extra utility from keeping himself (and others) in the dark about the true quality of the project because it allows him to remain in control while “cherishing the dream.”¹ Paying the cost of evaluating the project may also require raising capital from outside investors, diluting the founder’s control. And if there

¹ In his study of independent Canadian inventors who paid for an outside expertise of their ideas, Astebro [2003] found that many of them still pursued their ideas despite a negative recommendation. Presumably, the ex post utility of those inventors could have been improved had they not sought the expertise in the first place.
are cross-cultural differences in compensating utility differentials, the evaluation cost parameter in our model will vary across countries even if all other things are the same.

Section I of the paper presents the model. Section II contains some extensions and also examines empirical implications. Section III takes a look at the data using a unique data set on Japanese biotechnology startups, which is representative of all startups in the industry, not just a select group of very successful businesses. Section IV concludes.

1. A parsimonious model of CEO turnover

Startups differ in the entrepreneurial ability, $x$, of their founders. Each startup is also endowed with a project, the quality of which, $z$, differs over startups. A startup’s value is $xz$. Thus the quality of the project and the ability to develop it are complements.

Among startups, $x$ is distributed according to the cumulative distribution function $F(x)$ over $[0,x_{\text{max}}]$, where $x_{\text{max}}$ is finite and $x$ has strictly positive density over its support. Ideas are either good or useless: $z=\{0,1\}$. A fraction $\lambda$ of ideas is good, and the fraction $1-\lambda$ is useless; $\lambda$ does not depend on $x$, so all startups are equally likely to have a good project.

Entrepreneurial ability $x$ is known. Working on a project is a full-time activity, so an entrepreneur can handle at most one project, either his own or someone else’s. The wage of an entrepreneur who works to develop someone else’s project is determined in a competitive market and is denoted by $w(x)$. All agents are risk-neutral and maximize expected income (utility).

A startup has two options: (i) to work on a project of uncertain quality at no cost (the

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2 See [http://founderresearch.blogspot.com/2008/07/rich-vs-king-around-world.html](http://founderresearch.blogspot.com/2008/07/rich-vs-king-around-world.html), which shows that Japanese founders attach higher utility to independence than do US founders. This may explain at least part of lower turnover rates from founders to non-founder CEOs in our data on Japan as compared to the US data in Kaplan et al. [2009].
“no-evaluation option”), or (ii) to spend \( C > 0 \) to learn the quality of the project. Note that \( C \) can represent dollars or “utils” or both. Startups can hire entrepreneurs to develop projects. If a startup hires an entrepreneur with ability \( x’ \), the startup uses its own project, \( z \), and the entrepreneurial ability of the entrepreneur it has hired, \( x’ \). The value of such a startup will thus be \( x’z \).

We assume the following sequence of events:

1. A continuum of startups forms.
2. Startups choose whether to incur \( C \) and learn the quality \( z \) of the project. The quality of the project of a startup that paid \( C \) becomes public knowledge.
3. Startup founders choose whether to develop the project on their own or to hire an entrepreneur to develop the project.
4. The market for entrepreneurs clears with hired entrepreneurs of ability \( x \) receiving a competitive wage \( w(x) \). This market is Walrasian in that agents take \( w(x) \) as given and there are no out-of-equilibrium transactions.
5. Projects are developed and project values are realized.

\textit{Wage function for hired entrepreneurs}

In equilibrium there will be a marginal startup \( \hat{x} \) such that any startup founder with \( x \geq \hat{x} \) will pay to evaluate the quality of his project and will be hired to develop someone else’s good project in case his own \( z = 0 \), while all founders with \( x \) below \( \hat{x} \) will not be hired to develop others’ projects even if their own projects turn out to be useless. The ability of the marginal hired entrepreneur \( \hat{x} \) “pins down” the wages received by all hired entrepreneurs
because in equilibrium all good projects are the same and hence owners of good projects who hire entrepreneurs to develop them must be indifferent as to which entrepreneur to hire (i.e., hired entrepreneurs receive efficiency wages, reflecting the differences in their ability – cf. Holmes and Schmitz [1990]). Denote the wage of the marginal hired entrepreneur by \( w(\hat{x}) \). The startup founder who hires \( \hat{x} \) receives income equal to \( \hat{x} - w(\hat{x}) \) from his project, and all other founders must receive the same income from hiring entrepreneurs of ability \( x \). Hence, the wage function of entrepreneurs hired to develop projects will be given by \( w(x) = x - [\hat{x} - w(\hat{x})] \).

Equilibrium

**Figure 2. Equilibrium behavior by startup type**

We show later that unless \( C \) is very large, there is a unique equilibrium in which startups founded by individuals at high and low ends of entrepreneurial ability choose to evaluate their projects and high-\( x \) entrepreneurs with useless projects are hired to develop good projects for startups owned by low-\( x \) entrepreneurs. Startups founded by individuals of intermediate \( x \),
on the other hand, choose the no-evaluation option and do not hire entrepreneurs to develop their projects. We illustrate the equilibrium in Figure 2 and describe it below.

Key to equilibrium are two real numbers, \( \tilde{x} \) and \( \hat{x} \), where \( \tilde{x} < \hat{x} \). These numbers divide the set of \( x \)-values into three regions – bottom, middle and top. We first describe the \textit{ex ante} expected incomes in each region.

\textit{The Bottom Region}: \( x \leq \tilde{x} \) --- Startup founders in this region pay \( C \) and learn the quality of the project \( z \). If \( z = 0 \) they exit and earn nothing, if \( z = 1 \), they hire an entrepreneur \( x' \) from the top region and receive \( x' - w(x') = \hat{x} - w(\tilde{x}) \). Hence, the \textit{ex ante} expected income of a founder in this region is

\[
E_L = -C + \lambda(\hat{x} - w(\tilde{x})).
\]  
(1)

The founder \( \tilde{x} \) is indifferent between receiving the expected income given by (1) and developing the project of uncertain quality, which gives expected income equal to

\[
E_M = \lambda x.
\]  
(2)

Hence, we must have

\[
\tilde{x} = \hat{x} - w(\tilde{x}) - C/\lambda.
\]  
(3)

\textit{The Middle Region}: \( x \in (\tilde{x}, \hat{x}) \) --- Startup founders in this region develop their own projects of uncertain quality. Their expected income is therefore given by (2). Intuitively, startups in this region have too high \( x \) to be willing to pay for development by another entrepreneur, but are not good enough to pay for evaluation.

\textit{The Top Region}: \( x \geq \hat{x} \) --- Startup founders in this region pay \( C \) and learn the quality of the project \( z \). If \( z = 1 \), they proceed to develop it. If \( z = 0 \), they are hired by startups in the
bottom region and receive \( w(x) = x - [\hat{x} - w(\hat{x})] \). Hence, the \textit{ex ante} expected income of a founder in this region is

\[
E_{H} = -C + \lambda x + (1 - \lambda)(x - \hat{x} + w(\hat{x})) = x - (1 - \lambda)(\hat{x} - w(\hat{x})) - C. \tag{4}
\]

The founder \( \hat{x} \) is indifferent between (4) and the expected income from in (2):

\[
\lambda \hat{x} = \hat{x} - (1 - \lambda)(\hat{x} - w(\hat{x})) - C, \tag{5}
\]

so that the equilibrium wage at \( \hat{x} \) is given by:

\[
w(\hat{x}) = C/(1 - \lambda). \tag{6}
\]

Figure 3 illustrates how expected incomes in (1), (2) and (4) depend on \( x \).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Expected incomes and equilibrium (\( \lambda = 0.15, C = 6, x_{\text{max}} = 100 \))}
\end{figure}

\textit{Market Clearing}. --- Demand for entrepreneurs must equal their supply:

\[
\lambda F(\bar{x}) = (1 - \lambda)(1 - F(\bar{x})). \tag{7}
\]
Existence and uniqueness

If the evaluation cost $C$ is too high, the only equilibrium is where all startups choose to develop their own projects of unknown quality. To see this, notice that condition (3) implies that $\bar{x} - w(\bar{x}) > C/\lambda$ must hold in order for $\bar{x}$ to be positive. Condition (4) then implies that the value of the investment option for the highest-ability entrepreneur is bounded from above by $x_{\text{max}} - (1 - \lambda)C/\lambda - C = x_{\text{max}} - C/\lambda$. In order for the highest-$x$ founder to be willing to incur the evaluation cost, this value needs to be greater than the value of the no-evaluation option $\lambda x_{\text{max}}$.

We thus have

**Proposition 1 (No-evaluation equilibrium).** If $C \geq \lambda(1 - \lambda)x_{\text{max}}$, all startups develop their own projects of uncertain quality and there is no entrepreneurial turnover in equilibrium.

**Proof:** By the argument immediately above, if $x_{\text{max}} - C/\lambda \leq \lambda x_{\text{max}}$, no startup finds it worthwhile to incur $C$ to learn the quality of the project. But all projects are ex ante the same, so there is no gain for high-ability entrepreneurs to give up their own projects in order to be hired to develop some other projects with equally uncertain quality.

Initial evaluation costs are going to be particularly high if scientists with potentially commercializable ideas have little access to capital markets, if ideas are easily stolen or if non-pecuniary motivation is strong. Proposition 1 is thus consistent with the fact that prior to the introduction of the Bayh-Dole act in the US and its equivalents in other countries, founders of science-based startups would hold on to their projects while not making any significant investments for too long.

We now turn our attention to relatively low-$C$ environments.
Proposition 2 (Existence and uniqueness of equilibrium with evaluation). If
\[ C < \lambda(1 - \lambda)x_{\max}, \]  
project evaluation and entrepreneurial turnover occur in equilibrium. Furthermore, there is a unique pair \( \{\tilde{x}, \hat{x}\} \in (0, x_{\max}) \), where \( \tilde{x} = \hat{x} - C/\lambda(1 - \lambda) \) solves (3), \( \hat{x} > C/\lambda(1 - \lambda) \) solves (6) and the pair \( \{\tilde{x}, \hat{x}\} \) uniquely solves (7).

Proof: Substituting \( w(\hat{x}) = C/(1 - \lambda) \) from equation (6) into equation (3) we see that \( \tilde{x} = \hat{x} - C/\lambda(1 - \lambda) \) indeed solves equation (3). It remains to be shown that (i) for each value of \( \lambda \) and \( C \) that satisfy (8) there is a unique value of \( \hat{x} \) that solves
\[ \lambda F(\hat{x} - C/\lambda(1 - \lambda)) = (1 - \lambda)(1 - F(\hat{x})), \]  
and (ii) there is no supply of projects or demand for hired entrepreneurs coming from the middle region \( x \in (\tilde{x}, \hat{x}) \).

Step (i). At \( \hat{x} = C/\lambda(1 - \lambda) \), the left-hand side of (7’) is zero, while the right-hand side is positive, while at \( \hat{x} = x_{\max} \) the left-hand side is positive, while the right-hand side is zero. Also, since \( x \) has strictly positive density over its support, the LHS of (7’) is strictly increasing in \( \hat{x} \), while the RHS is strictly decreasing in \( \hat{x} \). Hence, exactly one intersection exists.

Step (ii). A startup founder hiring an entrepreneur with ability \( x \) has to pay the competitive equilibrium wage given by
\[ w(x) = x - \hat{x} - w(\hat{x}) = x - \hat{x} + C/(1 - \lambda). \]  
Since the expected income of founders in the middle region from developing their own projects is proportional to \( x \), we only need to show that it will not be in the interest of the lowest-\( x \) founder among them to hire an entrepreneur to develop his project, that is, that
\[ \lambda(\hat{x} + \varepsilon) > \lambda x - w(x) \] for an arbitrarily small \( \varepsilon \). Substituting from (9) and noting that \( \hat{x} = \hat{x} - C/\lambda \) , we obtain, after some manipulations, that

\[ \lambda\hat{x} + \lambda \varepsilon - \left[ \lambda x - w(x) \right] = (1 - \lambda)(x - \hat{x}) + \lambda \varepsilon > 0 \] for any \( \varepsilon > 0 \) since all projectless entrepreneurs for hire come from the top region where \( x > \hat{x} \). This completes the proof.

Figure 4 illustrates the determination of the equilibrium \( \hat{x} \). Note also that the parametric example in Figure 3 above corresponds to the equilibrium where it is assumed that \( x \) is distributed uniformly on \([0,100]\), giving \( \hat{x} = 92 \) and \( \hat{x} = 45 \).

**Figure 4. The determination of the equilibrium \( \hat{x} \).**

**Comparative statics**

The comparative statics of the model are given by the following

**Proposition 3.** The lower the evaluation costs \( C \) and the higher the fraction of good projects \( \lambda \) (at least if \( \lambda < 0.5 \)), the larger the fraction of startups that pay to evaluate the quality of the
projects and the larger the turnover of entrepreneurs in equilibrium.

Proof: See appendix. Note that \( \lambda < 0.5 \) is a sufficient but by no means a necessary condition for a higher fraction of good projects to lead to more entrepreneurial turnover in equilibrium.

As discussed above, evaluation costs to learn the quality of the project are likely to be lower if property rights for ideas are more clearly delineated, if there is an abundant supply of venture capital or if the preference for being rich is more strongly pronounced than preference for being “king”. Increased supply of better-quality (that is, more commercializable) projects can be expected to come from increased willingness of universities and basic research institutions in general to license their innovations and place more emphasis on the ties between university and industry research, the pattern that has been well-documented in studies on recent trends in university entrepreneurship (e.g., Thursby and Thursby [2002]).

II. Extensions and implications

Entry costs

Our model so far has ignored the cost of launching a startup. Assume now that in reality founding a startup entails some set-up cost \( b \). Then in the no-evaluation equilibrium (Proposition 1), the expected income for startups with \( x \in \left[ 0, \frac{b}{\lambda} \right) \) is negative, so such startups cannot be formed. In the equilibrium with evaluation, on the other hand, those startups will have a positive expected income, provided that \( \hat{x} - \frac{C}{\lambda(1-\lambda)} > \frac{b}{\lambda} \). Hence, for low enough \( C \) (and/or not too high \( b \)) the presence of entry cost will not discourage any startup from being formed. We conclude that a reduction in \( C \) (for example, through institutional reform or the development of venture capital market) may lead not just to an increase in CEO turnover but also
to more startups being launched to begin with. Moreover, all those new startups will pay evaluation costs and will be managed by high-ability entrepreneurs if their projects turn out to be good. We thus have

**Proposition 4.** *If there are entry costs, lowering evaluation cost C may result in new entry by startups formed by low-x entrepreneurs. These new entrants will also be the primary candidates for entrepreneurial turnover.*

*Slower (riskier) development without evaluation*

We have so far assumed that the speed and probability of developing a good project remained the same regardless of whether the project was evaluated or not. This may not be a realistic assumption. Without evaluation, time may be lost in searching for the right development direction. We also saw that part of evaluation costs may be the costs of establishing property rights over the idea. Without this, development may run into an unexpected hurdle if someone else patents a similar idea, so that startups that do not evaluate their ideas at the initial stage may risk losing even a good project before it can be developed.

Both these factors can easily be incorporated in the model by assuming that the expected value of the startup which does not incur the evaluation cost C is given by $\beta \lambda x$, where $\beta < 1$ can be interpreted either as the discount factor (if developing a project without evaluating it first takes time) or as one, minus the probability of losing a good project if it is not evaluated.

It turns out that most of the analysis in the previous section goes through, but there is a twist: if $\beta$ and C are low enough, all projects will now be evaluated in equilibrium and no founders develop projects of uncertain quality. More specifically, we have
**Proposition 5.** If \( C < \lambda (1 - \beta \lambda)^\alpha \), the evaluation option and entrepreneurial turnover occur in equilibrium. Furthermore,

- Either \( \hat{x} > \tilde{x} \) where
  \[
  \hat{x} = \frac{(1 - \lambda) \beta}{1 - \beta \lambda} \tilde{x} + \frac{C}{\lambda (1 - \beta \lambda)} \tag{10}
  \]
  and \( \hat{x} < C/(1 - \beta)\lambda \) solves
  \[
  \lambda F \left( \frac{1 - \beta \lambda}{\beta(1 - \lambda)} \hat{x} - \frac{C}{\beta \lambda (1 - \lambda)} \right) = (1 - \lambda) \left[ 1 - F(\hat{x}) \right], \tag{11}
  \]

- Or \( \hat{x} \leq \tilde{x} \) and \( \hat{x} \geq C/(1 - \beta)\lambda \) solves
  \[
  \lambda F(\hat{x}) = (1 - \lambda) \left[ 1 - F(\hat{x}) \right], \tag{12}
  \]

*In the latter case the no-evaluation option does not occur in equilibrium.*

**Proof:** see appendix.

The intuition is that if the risk of losing a good project is too high (or the time involved in developing a non-evaluated project is too long) compared to the cost of evaluation, then it is never optimal to hold on to a project of uncertain quality.

**Implications for entry and turnover**

Proposition 4 implies that if there are entry costs, lower evaluation costs will result in more startups, especially by scientists with ideas coming from basic research. Parallel to this, more startups founded around basic research ideas will use specialized entrepreneurial talent coming from non-academia to develop their ideas. Hence, the increase in the number of startups founded by academic researchers will tend to happen together with the **decrease** in the number of startups still managed by academic researchers after experiencing CEO turnover.
Implications for capital raised

In the equilibrium with evaluation (Proposition 2), startups managed by founder CEOs will be comprised of two subgroups. The first such subgroup will consist of startups with founders in the middle-$x$ range, choosing the no-evaluation option. The other subgroup will be startups with founders in the high-$x$ range who choose to evaluate their projects.

In contrast, all the startups that change CEOs will have chosen to pay the evaluation cost at the outset. Hence, if paying such cost requires raising capital from outside investors, we would expect the average startup that will experience entrepreneurial turnover in the future to raise more capital initially than the average startup that will not experience such turnover.

Consider now startups after the project evaluation and CEO turnover (if any) have already taken place. Assuming that the quality of unevaluated projects has yet to be revealed, among the startups that did not experience CEO turnover, the fraction \( \alpha = \frac{F(\hat{x}) - F(\bar{x})}{F(\hat{x}) - F(\bar{x}) + \lambda [1 - F(\hat{x})]} \) will have the value given by \( \lambda \int_{\hat{x}}^{\bar{x}} xdF(x) \). Note that especially if the fraction of good projects \( \lambda \) is low, \( \alpha \) will be close to 1, so that the average value of the startups that did not experience CEO turnover, equal to

\[
\tilde{V}(\hat{x}) = \alpha \lambda \int_{\hat{x}}^{\bar{x}} xdF(x) + (1 - \alpha) \int_{\hat{x}}^{\max} xdF(x)
\]  

(13) will be dominated by the first term on the right-hand side. Thus, an average business in this group will have low collateral, limiting its ability to raise capital to develop the project.

In contrast, all businesses that experienced entrepreneurial turnover and survived to the development stage have \( z = 1 \) and are also managed by entrepreneurs in the high-$x$ range. Hence, the average value of these businesses will be given by
\[ \hat{V}(\hat{x}) = \int_{\hat{x}}^{x_{\text{max}}} x dF(x), \tag{14} \]

which is greater than (13). Hence, using the value of the business as a collateral, the average business among those that went through entrepreneurial turnover will be able to raise more capital than the average business that did not go through such a turnover.

III. A look at the data

The implications from the model are consistent with accumulated anecdotal and statistical evidence. Some startups will flourish under founder-CEOs but cases like those of Bill Gates, Phil Knight or Anita Roddick are likely to be “the exceptions to the rule.” (Wasserman [2008], p. 2) In this section we probe the implications of our model employing unique data from two surveys conducted by Japan Bioindustry Association (JBA) with the support of the Hitotsubashi University Institution of Innovation Research (IIR).³

The data are unique because they represent a still extremely rare case where the sample is representative and not limited to successful startups (such as VC-backed startups or startups that have already conducted IPO). Just slightly over ¼ of the startups in the data reported having received financing from venture capital and less than 10 percent had conducted IPO or had specific plans to conduct IPO at the time of the surveys. Thus, we can compare various characteristics of the startups that move along by developing commercially promising projects with those of the startups that are basically not going anywhere, often for many years.⁴

³ See Braguinsky, Honjo, Nagaoka, and Nakamura [2010] for the detailed description of the data.
⁴ Interviews with founders have confirmed that many such startups are in fact guided by utility motives, from enjoying owning a company to using it as a vehicle for research. Successful startups are very different. The new CEO in one of those told us that the first thing he had to do was to limit the influence of academic founders.
Entry cohorts and turnover of entrepreneurs

Table 1. Evolution of entry and entrepreneurial turnover

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of startups</td>
<td>43</td>
<td>72</td>
<td>180</td>
<td>89</td>
</tr>
<tr>
<td>Fraction in total</td>
<td>11.20</td>
<td>18.75</td>
<td>46.88</td>
<td>23.18</td>
</tr>
</tbody>
</table>

- Startups with founder CEOs at the time of survey

| Fraction with startup technology from basic research | 38.46 | 40.62 | 55.13 | 69.84 |

- Fraction with CEOs

| Former scientists | 27.78 | 47.06 | 54.44 | 60.87 |

Formerly employed in:

| Academia | 5.56 | 14.29 | 21.51 | 39.13 |
| Large corporations | 27.78 | 42.86 | 39.78 | 28.99 |
| Other non-academia | 66.67 | 42.86 | 38.71 | 31.88 |

- Startups with non-founder CEOs at the time of survey

| Fraction with startup technology from basic research | 29.41 | 40.74 | 60.34 | 69.23 |

Fraction with CEOs

| Former scientists | 50.00 | 50.00 | 38.03 | 30.77 |

Formerly employed in:

| Academia | 0.00 | 28.57 | 16.90 | 7.14 |
| Large corporations | 47.06 | 50.00 | 50.70 | 50.00 |
| Other non-academia | 52.94 | 21.43 | 32.39 | 42.86 |

Note: Academia includes universities and public research corporations. The total number of respondents was 292 in 2008 and 281 in 2009 but for the purposes of the analysis in this paper we excluded the 2008 responses by 186 firms that responded to both surveys.

We first examine the evolution of types of startups by four entry cohorts: prior to 1990, 1990-1999, 2000-2004, and 2005-2009. As Japan introduced measures aimed at improving conditions for science-based startups, Proposition 4 implies that the number of startups by academic researchers should increase but those firms that experience CEO turnover should be...
increasingly managed by entrepreneurs with non-academic background.

The data in Table 1 provide strong support for these predictions. The sample is divided into startups managed by founders and those managed by non-founder CEOs at the time of the survey. The data show that both categories experienced an equally strong increase in the fraction of startups whose core technologies draw on basic research (developed at universities or public research corporations). Paralleling this, among the startups managed by founders, the fractions of those founded by former scientists and individuals formerly employed in academia increased dramatically (from less than 28 percent to more than 60 percent in the former category, and from less than 6 percent to more than 40 percent in the latter category).

But among the startups managed by non-founder CEOs, the fractions of those whose entrepreneurs are former scientists and academic employees actually fell sharply throughout the 1990s and the 2000s. Hence, while policy measures aimed at promoting startups based on academic research have resulted in a dramatic increase in the number of new startups in the biotechnology industry founded by scientists and individuals employed in academia, they seem to have also resulted in more frequent replacement of scientists and academics by specialized entrepreneurs in the startups experiencing CEO turnover.

CEO turnover and startup capital at the time of founding

Startups experiencing entrepreneurial turnover at some point in the future should on average be raising more capital at the time they are founded than startups that never experience such turnover. To test this implication, we estimate the following regression:

\[
\ln C_{0i} = \alpha + \beta_1 ET_i + \gamma X_i + \epsilon_i, \quad (15)
\]
where $C_{0i}$ is startup $i$’s paid capital in the year it was founded, $ET_i$ is the dummy equal to 1 if the startup was managed by a non-founder CEO at the date of the survey and zero otherwise, and $X_i$ is a vector of controls. Since the amount of initial capital might be affected by the timing of entry, we include founding year dummies in the vector of controls $X_i$ and also seven dummies corresponding to different areas of activity of the startup.

**Table 2. Estimations of regression (15)**

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Log paid capital in founding year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-founder CEO</td>
<td>Coefficient 0.723 *** 0.744 **</td>
</tr>
<tr>
<td>Basic research core technology</td>
<td>Coefficient -0.777 ***</td>
</tr>
<tr>
<td>Venture capital financing dummy</td>
<td>Coefficient -0.174</td>
</tr>
<tr>
<td>US patent activity dummy</td>
<td>Coefficient 0.992 ***</td>
</tr>
<tr>
<td>Activity: new drug development</td>
<td>Coefficient 0.461 * 0.151</td>
</tr>
<tr>
<td>Constant</td>
<td>Coefficient 2.870 *** 3.084 ***</td>
</tr>
<tr>
<td>Other controls</td>
<td>Founding year dummies, activity area dummies</td>
</tr>
<tr>
<td>Number of firms</td>
<td>243</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.074</td>
</tr>
</tbody>
</table>

Note: *** indicates that the coefficient is significant at 1 percent level, ** at 5 percent level, and * at 10 percent level.

The specification presented in the first column in Table 2 contains only the above basic controls. We exclude very young and very old firms (less than 3 and more than 25 years of age at the time of the survey), even though the results are robust to using all firms in the sample. The prediction of the model is that the coefficient $\beta_1$ should be positive and significant, and the
estimates indicate that startups that experience CEO turnover in the future have initial paid capital more than twice as large as startups that don’t experience such a turnover (exp(0.723)-1). Founding year dummies are jointly not statistically significant but areas in which startups conduct their primary activity are jointly significant at 10 percent level.

In the specification in the second column of Table 2 we add controls for the project technology and the intrinsic quality of the project. To control for the technology input we use the dummy equal to one if the core technology at the time of entry came from basic research and zero otherwise. To control for the intrinsic quality of the project we include the dummy equal to 1 if the startup applied for or was granted a patent in the U.S. and 0 otherwise and the dummy equal to 1 if the startup received venture capital financing and zero otherwise.

The estimation results show that the extra controls have virtually no effect on $\beta_1$. Among the controls themselves, patenting activity in the US, not surprisingly, has a strong positive impact on initial capital but core technology coming from basic research (that is, developed in a university or a public research corporation) has a strong negative effect (we also tried including the interaction term between basic core technology and CEO turnover but the coefficient was small and statistically insignificant). It is also interesting to note that the coefficient on venture capital financing dummy is statistically insignificant and has the “wrong” sign. This collaborates the view expressed by founders we have interviewed that Japanese venture capital funds rarely take a proactive role of helping good startups at the outset.

**CEO turnover and raised capital at the survey date**

The amount of capital raised as the firm develops the project should also be positively
associated with CEO turnover. To probe this, we estimate a regression similar to (15) but with (the log of) paid capital at the time of the survey as the dependent variable:

\[
\ln C_i = \alpha + \beta_i ET_i + \gamma X_i + \epsilon_i, \tag{16}
\]

where \( C_i \) is the paid capital at the time of the survey. We once again control for areas of activity and non-parametrically for firm age by including startup founding year dummies.

Table 3. Estimations of regression (16)

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Log paid capital in survey year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
</tr>
<tr>
<td>Non-founder CEO</td>
<td>0.600</td>
</tr>
<tr>
<td>Basic research core technology</td>
<td>-0.305</td>
</tr>
<tr>
<td>Venture capital financing dummy</td>
<td>1.117</td>
</tr>
<tr>
<td>US patent activity dummy</td>
<td>0.943</td>
</tr>
<tr>
<td>Log initial paid capital</td>
<td>0.297</td>
</tr>
<tr>
<td>Activity: new drug development</td>
<td>1.960</td>
</tr>
<tr>
<td>Constant</td>
<td>3.286</td>
</tr>
<tr>
<td>Other controls</td>
<td>Founding year dummies, activity area dummies</td>
</tr>
<tr>
<td>Number of firms</td>
<td>250</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.278</td>
</tr>
</tbody>
</table>

Note: *** indicates that the coefficient is significant at 1 percent level, ** at 5 percent level, and * at 10 percent level.

The estimation results are presented in Table 3. The first two columns present the results of estimating the two same specifications as in Table 2. The specification in the third column also includes the (log of) initial paid capital \( C_{0i} \) as an additional control. We also
highlight the coefficient on new drug development as it turns out to be a major determinant of how much capital the startup has to raise along the way.

Once again, the estimates support the model. Other things equal, startups that went through CEO turnover have 82 percent \((\exp(0.6)-1)\) higher capital than startups that didn’t in the baseline specification. Controlling for the nature of the technology, venture financing and patents in the US, the effect is still more than 70 percent and statistically highly significant. And even controlling for initial paid capital, businesses that changed their CEOs from founders to non-founders are still estimated to have capital 40 percent higher than businesses where founders run the show, although the statistical significance of the coefficient diminishes.

Finally, in Table 4 we look at the stages of the IPO process in relation to CEO turnover. The respondents to the 2008 survey were asked to answer the question about their IPO event or intention. The four possible answers were (i) “has already conducted IPO”, (ii) “intend to conduct at IPO at a specific date and market” (specifying the date and the market), (iii) “consider IPO but no specific plans at the moment”, and (iv) “have no IPO plans”. Before presenting the regression results, the top part of Table 4 shows the summary statistics. Firms with non-founder CEOs are more likely to have already conducted IPO or to have specific plans to conduct IPO than firms managed by founders, and they are also less likely to have no intention of conducting IPO at all. The statistical power of the mean comparison \(t\)-test is low because of the limited number of observations, but with regard to having no intention of IPO the one-sided test is statistically significant at 5 percent level and the two-sided test is significant at 10 percent level (in the two other cases only the one-sided test is statistically significant at 10 percent level).
Table 4. CEO turnover and IPO stages

<table>
<thead>
<tr>
<th>Stages of IPO:</th>
<th>Firms managed by:</th>
<th>Non-founder</th>
<th>Founder</th>
<th>t-test (mean comparison)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have conducted IPO</td>
<td>Fractions</td>
<td>0.064</td>
<td>0.024</td>
<td>0.081</td>
</tr>
<tr>
<td>Have specific IPO plan</td>
<td></td>
<td>0.096</td>
<td>0.049</td>
<td>0.090</td>
</tr>
<tr>
<td>No IPO intention</td>
<td></td>
<td>0.383</td>
<td>0.500</td>
<td>0.966</td>
</tr>
<tr>
<td>Number of observations</td>
<td></td>
<td>94</td>
<td>164</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th></th>
<th>IPO stage (ordered probit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-founder CEO</td>
<td>Coefficient</td>
<td>0.420 **</td>
</tr>
<tr>
<td></td>
<td>St. Error</td>
<td>0.192</td>
</tr>
<tr>
<td>Core technology changed since founded</td>
<td>Coefficient</td>
<td>-0.299</td>
</tr>
<tr>
<td></td>
<td>St. Error</td>
<td>0.218</td>
</tr>
<tr>
<td>US patenting activity dummy</td>
<td>Coefficient</td>
<td>0.523 **</td>
</tr>
<tr>
<td></td>
<td>St. Error</td>
<td>0.216</td>
</tr>
<tr>
<td>Log initial paid capital</td>
<td>Coefficient</td>
<td>-0.027</td>
</tr>
<tr>
<td></td>
<td>St. Error</td>
<td>0.078</td>
</tr>
<tr>
<td>VC financing dummy</td>
<td>Coefficient</td>
<td>1.097 ***</td>
</tr>
<tr>
<td></td>
<td>St. Error</td>
<td>0.219</td>
</tr>
<tr>
<td>Other controls</td>
<td>Area of activity and founding year dummies</td>
<td></td>
</tr>
<tr>
<td>Number of observations (firms)</td>
<td></td>
<td>221</td>
</tr>
<tr>
<td>Pseudo R-squared</td>
<td></td>
<td>0.168</td>
</tr>
</tbody>
</table>

Notes: P-values in mean comparison t-test with unequal variance. ** indicates that the coefficient is significant at 1 percent level, *** at 5 percent level, and * at 10 percent level. “IPO stage” refers to four answer categories as described in the main text.

The bottom part of Table 4 presents the results of estimating an ordered probit regression where the four answers above are classified as four different stages of IPO process, with (i) being the highest and (iv) the lowest stage. Both with and without extra controls for changes in core technology, patenting activity in the US, log initial capital and venture capital financing, the non-founder CEO dummy is positively and statistically significantly (at 5 percent
level) associated with the startup being further along its way to conducting an IPO. Areas of activity are jointly statistically significant at 1 percent level, but founding year dummies are jointly statistically insignificant. Among other controls, US patenting activity dummy and venture capital financing are predictably strongly positively associated with IPO, but including these controls does not affect the coefficient on entrepreneurial turnover (if anything, it makes it even somewhat larger).

IV. Conclusions and discussion

We have presented a parsimonious model where science-based businesses started by academic researchers with relatively low entrepreneurial ability may be taken to the commercialization stage by high-ability entrepreneurs who do not have a project of their own. In equilibrium, startups that experience CEO turnover coexist with startups that are continuously managed by their founders. The model predicts that the startups that change CEOs will tend to outperform the startups that are managed by their founders in terms of capital raised and will also have higher success rates.

Startups that are developed by high-ability entrepreneurs incur costs to learn the quality of their project and discard useless projects. This insight is somewhat similar to the “cash-out or flame-out” idea explored by Arora and Nandkumar [2009]. But in our model it is not just entrepreneurs with the highest opportunity cost who choose the evaluation option, but entrepreneurs with the lowest opportunity cost also do the same, in anticipation of hiring high-ability entrepreneurs to develop their project if it turns out to be good.

The basic framework of the model is closely related to the ideas first explored in
Jovanovic and Braguinsky [2004]. In that paper we assumed, however, that projects, and not entrepreneurial talent, were traded in the market. It should be emphasized that all what really matters is the idea that good projects are matched with high-ability entrepreneurs, and this can equally happen through projects changing hands if the market for ideas were to replace the market for entrepreneurs, without changing the nature of the equilibrium. Our decision to adopt the market for entrepreneurs rather than the market for projects for the purposes of this paper was driven partly by theory and partly by empirical considerations. From a theoretical perspective, we agree with the concept (e.g., in Zingales [2000]) that while projects may indeed more easily change hands than management teams in traditional types of business, in science-based business the tacit knowledge of the founder might be essential also at the development stage, making it difficult to move the project. And on the empirical side, our data indicate that even though entrepreneurial turnover is quite common, the controlling stake in the firm for most part is retained by the founder despite the change in the CEO (Honjo et al. [2009]).

When tested against the data on a representative sample of biotechnology startups in Japan, the main predictions of the theory are strongly supported. Both theory and empirical findings supporting it indicate that at the stage of commercialization, science-based businesses may after all be subject to many of the same kind of regularities as non-science-based businesses, so that the emergence of biotechnology and other science-based industries in the past couple of decades does not necessarily require drastically changing the established theory of the firm.

Our study has important policy implications. Establishing a smoothly functioning market for entrepreneurial talent, including lowering the costs of evaluating early on the
commercial potential of an idea coming from basic research and reducing incentives for academic researchers to hold on to their projects for too long, may be at least as important as supporting the basic research to produce such ideas in the first place. Our findings also imply that science-based businesses should be proactively seeking experienced managers if they want to evaluate and develop their projects with a view to generating high returns. Zingales [2000] conjectured that firms organized around high-level human capital might well be unstable and dysfunctional. Our theory and evidence show that such an outcome is not inevitable.

The nature of science-based business and its implications for the theory of the firm and industrial organization have been the subject of a hot debate in the literature. Our paper does not aim to resolve this debate once and for all. But it suggests that “traditional” theories of markets and firm can be fruitfully applied to understanding and analyzing science-based businesses just as they have been applied to more conventional types of businesses and industries.

References
Optimism, Risk Seeking or Skewness Loving?” *Economic Journal*, 113 (January), 226-239.


Appendix

Proof of Proposition 3.

Totally differentiate the equilibrium condition (7') to obtain

$$
\left[ \lambda f(\hat{x}) + (1 - \lambda)f(\hat{x}) \right] d\hat{x} - \frac{f(\hat{x})}{1 - \lambda} dC
+ \left[ F(\hat{x}) + (1 - F(\hat{x})) + \lambda f(\hat{x})C \frac{1 - 2\lambda}{\lambda^2 (1 - \lambda)^2} \right] d\lambda = 0.
$$

Hence, we have

$$
\frac{d\hat{x}}{dC} = \frac{f(\hat{x})}{(1 - \lambda) \left[ \lambda f(\hat{x}) + (1 - \lambda)f(\hat{x}) \right]} > 0,
$$

and

$$
\frac{d\hat{x}}{d\lambda} = \left[ \frac{F(\hat{x}) + (1 - F(\hat{x})) + \lambda f(\hat{x})C \frac{1 - 2\lambda}{\lambda^2 (1 - \lambda)^2}}{\left[ \lambda f(\hat{x}) + (1 - \lambda)f(\hat{x}) \right]} \right],
$$

which will be less than zero if \( \lambda < 0.5 \) (which is a sufficient, but not necessary condition).

Proof of Proposition 5.

The proof is by construction. To begin with, notice that for \( \hat{x} \) close to \( C/(1 - \beta \lambda) \lambda < C/(1 - \beta) \lambda \) the left-hand side of (11) tends to zero, while the right-hand side tends to \( (1 - \lambda) \left[ 1 - F(C/(1 - \beta \lambda) \lambda) \right] > 0 \), since \( x_{\text{max}} > C/(1 - \beta \lambda) \lambda \) by assumption. Also the left-hand side of (11) is strictly increasing in \( \hat{x} \), while the right-hand side is decreasing in it. There are two possible cases.

--- Case (i). There is some \( \hat{x}^* < C/(1 - \beta) \lambda \) such that (11) is satisfied with equality at \( \hat{x} = \hat{x}^* \).

Conditions (10) and (11) yield, after some manipulations, that \( \hat{x} > \bar{x} \) at this \( \hat{x}^* \). Then (11) and (10) imply that the number of entrepreneurs from the top region moving to work
with projects owned by the startups with \( z = 1 \) in the bottom region is 
\[
\lambda F(\hat{x}) = (1 - \lambda)[1 - F(\hat{x})].
\]
Hence, (11) is indeed the desired equilibrium.

--- Case (ii). Assume now that at \( \hat{x} = C/(1 - \beta)\lambda \) there is still excess supply of entrepreneurs for hire (the left-hand side of (11) is smaller than the right-hand side). This means that \( \hat{x} \) has to go up further. But if \( \hat{x} > C/(1 - \beta)\lambda \), the no-evaluation option becomes less attractive than paying \( C \) and letting another entrepreneur develop the project if \( z = 1 \) for founder \( \tilde{x} \), so that only the bottom region \( x \in [0, \hat{x}) \) and the top region \( x \in [\hat{x}, x_{\text{max}}] \) remain as part of an equilibrium (notice that \( \hat{x} \leq \tilde{x} \) if and only if \( \hat{x} \geq C/(1 - \beta)\lambda \)).

Since the left-hand side of (12) tends to \( \lambda > 0 \) as \( \hat{x} \to x_{\text{max}} \), while the right-hand side tends to zero as \( \hat{x} \to x_{\text{max}} \), there will be some \( \hat{x}^* \in (C/(1 - \beta)\lambda, x_{\text{max}}) \) such that the equilibrium condition (12) is satisfied with equality. Note that in case (ii) founder \( \hat{x}^* \) is indifferent between paying \( C \) and receiving \( \hat{x} - w(\hat{x}) \) with probability \( \lambda \), on the one hand, and choosing the evaluation option with the expected private value \( E_{H} \) as in (4), on the other hand. Hence, we must have 
\[
\lambda(\hat{x} - w(\hat{x}^*)) - C = \hat{x}^* - (1 - \lambda)(\hat{x}^* - w(\hat{x}^*)) - C, \quad \text{or} \quad w(\hat{x}^*) = 0.
\]
In other words, the \textit{ex post} marginal hired entrepreneur’s competitive wage is zero, equal to his opportunity cost of exit.