Dynamics of Shared Capitalism Policies in a Startup Company

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Abstract

Shared capitalism is a diverse set of compensation practices through which worker pay, or wealth, depends on the performance of the firm or work group; compensation practices include employee ownership, stock options, and profit sharing. Empirical studies on whether employee ownership improves firm performance offer mixed results. Kaarsemaker (2006), in a 30-year review of the literature, documented that “two-thirds of 129 studies on employee ownership and its consequences found favorable effects relating to employee ownership, while one-tenth found negative effects. However, favorable effects do not appear to come about automatically, and the specific conditions under which they do are largely unknown.”

This dissertation attempts to address the question: under what conditions do shared capitalism policies improve firm performance? A system dynamics model of high performance work systems estimated using the NBER Shared Capitalism dataset and calibrated to a clean technology startup company is presented. The model provides an explicit causal mechanism to explain how various shared capitalism policies and HR practices influence employee behaviors that drive business processes, and how those business processes interact with market conditions to generate firm performance in a dynamic feedback system.

Simulation analysis explaining how various combinations of salary, stock grants, stock options, profit sharing and employee participation influence employee behaviors and firm performance offers insights into the dynamics of shared capitalism policies. One critical insight is that employee ownership and profit sharing create and mediate the strength of the reinforcing feedback loops from firm performance to employee behavior. Salary and participation are direct effects that influence job satisfaction and productivity but do not close the firm performance-employee behavior loop. Employee ownership along with participation effort improves firm performance significantly because closing the firm performance-employee behavior loop amplifies the direct effects of salary and participation. Thus, the more wealth is shared through broad-based employee ownership, the more wealth is created, given the appropriate conditions. Eleven propositions on the conditions under which shared capitalism policies improve firm performance are presented.

Thesis Supervisor: John D. Sterman
Title: Jay W. Forrester Professor of Management
To my parents

for

their conditional love, understanding and support.
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1. INTRODUCTION

1.1 Motivation: the Importance of Shared Capitalism

"Shared Capitalism" is a pervasive phenomenon in the American economy. Kruse, Freeman and Blasi (2010) define "Shared Capitalism" as "a diverse set of compensation practices through which worker pay or wealth depends on the performance of the firm or work group." They found that almost half of US employees participate in some form of shared capitalism, such as employee ownership, individual employee stock ownership, stock options, profit sharing or gain sharing. The 2006 General Social Survey estimates that 47 percent of workers are covered by at least one such form, with 38 percent having profit sharing, 27 percent having gain sharing, 18 percent owning their company's stock, 9 percent holding company stock options, and 5 percent receiving company stock options in any year. Based on these figures, shared capitalism covered 53.4 million American workers in 2006 (Kruse, Freeman and Blasi 2010).

A substantial amount of overlap exists among shared capitalism plans. Over three-fourths of workers who own company stock also have profit sharing or stock options, and workers with profit sharing often participate in other programs as well. These patterns suggest that some firms combine the longer-term incentives associated with employee stock ownership or deferred profit sharing in retirement accounts with shorter-term incentives such as cash bonuses and stock options, presumably to maximize worker commitment and effort over different time horizons, as well as to combine more and less risky shared capitalism practices (Kruse, Freeman and Blasi 2010).

1.2 Research Question: Under What Conditions Do Shared Capitalism Policies Improve Firm Performance?

Given the pervasiveness of shared capitalism, it is no surprise that scholars have been studying employee ownership for a long time. On the question "does employee ownership improve firm performance?" results from empirical studies, while predominately positive, are mixed. Kaarsemaker (2006), in a 30-year review of the
literature, found that “two-thirds of 129 studies on employee ownership and its consequences found favorable effects relating to employee ownership, while one-tenth found negative effects. However, favorable effects do not appear to come about automatically, and the specific conditions under which they do are largely unknown.” Why is that? Kaarsemaker and Poutsma (2006) argue that “one of the reasons for the relative weakness of the results from empirical research on the consequences of employee ownership is that, as yet, the theory behind many of the studies on the effects of employee ownership has been underdeveloped. In particular, no research has been done on comprehensive models of employee ownership and the broader human resource management system.”

This dissertation aims to address the literature gap by building a dynamic causal model of high performance work systems (HPWS). Instead of asking “do shared capitalism policies improve firm performance?” I ask “under what conditions do shared capitalism policies improve firm performance?” – avoiding any assumption that employee ownership is a panacea, and instead inquiring into the conditions under which it produces better or worse effects. To answer this question, we need to untangle the underlying causal mechanisms that determine how various shared capitalism policies influence employee behavior and firm performance.

1.3 Research Method

Most of the empirical studies focus on estimating the relationship between some forms of shared capitalism and firm performance through survey data and regression analysis. To go beyond estimating a specific linkage in the HR system and develop a theory of the causal mechanism from HR practices to performance, I employ a system dynamics simulation approach that is quite different from studies in the existing literature.

System dynamics (SD) is a formal modeling and simulation method designed to explain dynamic behavior generated from its underlying causal structure, characterized by feedback, non-linearity and time delay (Forrester 1961, Sterman 2000). By explicitly modeling the causal paths from HR practices to performance, and simulating the dynamic
behavior of performance under various HPWS scenarios, one is able to generate and test a set of causal theories explaining the impact of HPWS on performance.

My approach involves three main steps, using mixed survey data, case study and simulation methods.

1. **Model Building:** I build a system dynamics model of HPWS estimated using the NBER Shared Capitalism dataset and calibrated to a clean technology startup company. The model provides an explicit causal mechanism to show how various shared capitalism policies and HR practices influence employee behaviors that drive business processes, and how those business processes interact with market conditions to generate firm performance in a dynamic feedback system. This model is built on Miller’s (2007) model of clean technology startup companies. My contribution is to add a detailed HPWS with various shared capitalism policies such as salary, stock grants, stock options, profit sharing and employee participation. To build the HPWS structure, I performed a thorough literature review on the existing theoretical and empirical findings of employee ownership and Strategic Human Resource Management (SHRM), and formally modeled them in a system dynamics framework.

2. **Model Estimation and Calibration:** Since employee ownership effects are the main focus of this study, I have estimated the non-linear functional forms of various employee ownership effects by regression analysis using the NBER Shared Capitalism dataset (Kruse, Freeman and Blasi 2010). To calibrate this model, I conducted interviews and collected archival data of an early-stage clean technology startup company. Given the inherent limitation of an early-stage startup when there are no later-stage time-series data, company data was used to parameterize the initial conditions of the model. I interviewed the executives to identify their decision-making rules for pricing, financing, human resource and compensation policies and their projections for business performance. The base run of the model represents closely the executives’ expectations and confirms the general patterns of typical startup companies.
There are three reasons why I focus on a startup company. First, shared capitalism policies such as stock options, stock grants and profit sharing are important motivational tools in addition to salary in cash-constrained startup companies (Blasi, Kruse and Bernstein 2003). Second, I am interested in studying the long-term dynamic effects of shared capitalism policies across the firm life cycle, starting from the founding stage. Third, research has shown that founders have long-term imprinting effects on organizational design and policies (Burton 2001, Burton and Beckman 2007, Beckman and Burton 2008). Understanding the impact of various shared capitalism policies since the founding phase is highly relevant to the practice of entrepreneurship.

3. Policy Analysis: I conduct simulation analyses to study how various combinations of salary, stock options, stock grants, profit sharing schemes and employee participation efforts influence employee behavior and firm performance over time. The simulation results offer insights into the dynamic effects of shared capitalism policies. Eleven propositions on the conditions under which shared capitalism policies improve firm performance are presented. Sensitivity analysis is conducted to ensure the robustness of the analyses and guide future research.

1.4 Contributions

The main contributions of this dissertation are, first, while the majority of the SHRM and HPWS literature tends to focus on testing a specific linkage in isolation, I provide a dynamic causal feedback model of an integrated HPWS linking HR policies, employee behaviors, business processes and firm performance. Second, eleven propositions on the dynamic effects of shared capitalism policies are presented. These propositions can serve as a guide for future empirical studies to test the dynamic hypotheses stated in the propositions.

1.5 Outline of Dissertation
This chapter presents the importance of shared capitalism policies and the overall approach to address the research question: under what conditions do shared capitalism policies improve firm performance?

**Part I: Literature Review**

Chapter 2 reviews the theoretical and empirical literature in employee ownership and identifies the gaps in the literature.

Chapter 3 reviews the literature in SHRM and HPWS, and identifies five methodological challenges in the literature.

**Part II: Method**

Chapter 4 describes the system dynamics method and how system dynamics can address the methodological challenges in SHRM and HPWS.

Chapter 5 presents an overview of the research methods used in this dissertation, such as the methods for model building, model estimation and calibration and model analysis.

**Part III: Model Description**

Chapter 6 presents a high-level overview of the model such as the model framework, the firm structure, model sectors and a causal loop diagram of HPWS.

Chapter 7 describes the key model sectors and model formulations in detail and the initial conditions used to calibrate the model.

Chapter 8 presents the NBER Shared Capitalism dataset and the regression estimates of the non-linear functional forms of various employee ownership effects.
Chapter 9 describes the employee participation structure in the model, such as the process of building participation culture and its impact on employee behavior.

**Part IV: Model Analysis**

Chapter 10 describes the business strategy, employee behavior and firm performance in the base case scenario.

Chapter 11 presents policy analysis of various shared capitalism policies and offers eleven propositions regarding the dynamic effects of shared capitalism policies on employee behavior and firm performance.

Chapter 12 presents two sets of sensitivity analyses: one on the effect of financial compensation on job satisfaction and the other on a sudden decrease in sales productivity.

Chapter 13 showcases the Clean Technology Startup Management Flight Simulator, a gaming interface developed for teaching dynamic strategies of running a startup company.

**Part IV: Conclusion**

Chapter 14 summarizes the research question, methods and findings of this dissertation.

Chapter 15 presents the theoretical, empirical, methodological and teaching contributions offered by this thesis.

Chapter 16 describes the limitations and suggests further research in model analysis, empirical studies and model development.
PART I: LITERATURE REVIEW

2. EMPLOYEE OWNERSHIP

2.1 Theories of Employee Ownership

Employee ownership takes many different forms, ranging from simple bonuses paid in employee shares (which can hardly be called "ownership"); to more structured and indirect schemes with recurrent payments to employees' investment accounts; to periodic trade administered by a trust (which is a bit more like real "ownership"); and to worker/producer cooperatives (which come closest to real "ownership").

Toscano (1983) developed a typology of employee ownership with three general types: direct ownership, employee stock ownership plans (ESOPs), and producer cooperatives. Within these types, employee ownership forms vary according to at least eight different factors: the function of the shares, how the shares are allocated and administered, the principles of control, and the provisions for dealing with the following: sale and transfer, share concentration, new employees, and outside investors (Toscano, 1983).

Blasi, Kruse and Bernstein (2003) described the "culture of egalitarianism" pioneered by high-tech startups, or what they called "partnership capitalism." Partnership capitalism in high-tech startups has two basic strands: empowerment (teamwork, participation in decision-making, employee board representatives, and information sharing) and share options (ownership) for everyone.

Rosen, Case and Staubus (2005) derived a model – the "equity model" – of how the business has to be structured and run in order to succeed in reframing mindsets and changing behaviors. This equity model contains three key elements: first, stock ownership is significant enough that "I" matter to all the employees' financial future. The second is an ownership culture in which people think and feel like owners. The third element is a shared understanding of key business disciplines and a common commitment to pursuing them.
Rosen and Rodgers (2007) proposed six essential rules for creating an ownership culture. First, provide a financially meaningful ownership stake, enough to serve an important part of each employee’s financial security. Second, provide ownership education teaching people how the ownership plan works. Third, train people in business literacy so they have the tools to think like entrepreneurs about company performance. Fourth, share performance data about how the company is doing overall and how each work group contributes to that. Fifth, share profits through bonuses, profit sharing, or other tools. Six, build employee involvement not just by allowing employees to contribute ideas and information but by making that part of their everyday work through teams, feedback opportunities, devolution of authority, and other structures.

Kaarsemaker and Poutsma (2006) developed a model expressing an “ownership high-performance work system.” They proposed a set of organizational practices that translate the ownership rights (Table 2.1) and argued that in order to be effective, an HRM system with employee ownership should include the following HRM practices: participation in decision-making, profit sharing, information sharing, training for business literacy and mediation. The relationships between these core HRM practices are partially conditional, and partially multiplicative. An employee cannot be a real owner if he or she has no say, if he or she does not share in the returns, if he or she has no information about the business or does not understand the information that is being shared – i.e., the employee owner must be “business literate” (Rousseau and Shperling, 2003). The presence or absence of these core HRM practices determines whether or not the HRM system consistently sends the message that employees deserve to be owners and that they are taken seriously as such.
Table 2.1: Translation of Ownership Rights into Organizational Practices

<table>
<thead>
<tr>
<th>Ownership Rights</th>
<th>Corporate Governance Practices</th>
<th>HRM Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use</td>
<td>• Voting rights</td>
<td>• Participation in decision-making</td>
</tr>
<tr>
<td></td>
<td>• Shareholders’ meetings</td>
<td>• Information sharing</td>
</tr>
<tr>
<td></td>
<td>• Board membership</td>
<td>• Training for business literacy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mediation</td>
</tr>
<tr>
<td>Returns</td>
<td>• Dividends</td>
<td>• Profit sharing</td>
</tr>
<tr>
<td>Sale</td>
<td>• Simply decide to sell shares</td>
<td>• Participation in decision-making about employee ownership</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sharing of information with regard to employee ownership</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Training for business literacy to understand and be capable of the above</td>
</tr>
</tbody>
</table>

Source: Kaarsemaker and Poutsma (2006)

2.2 Empirical Studies of Employee Ownership

Kaarsemaker (2006) conducted a thorough literature review of employee ownership over the past thirty years. He found a prototypical quantitative study on the effects of employee ownership:

- Focuses on company-level issues from either a financial perspective or a people perspective;
- Uses cross-sectional data (i.e., data from a single point in time);
- Is limited to a single country (the U.S.);
- Analyzes data from many companies if it applies a financial perspective, but from a small number of companies if it applies a people perspective;
- Concentrates on a single type of employee ownership, mostly ESOPs;
- Finds favorable effects relating to employee ownership;
- Compares shareholders with non-shareholders, or employee ownership companies with non-employee ownership companies; and
- Ignores interaction effects.
Out of the 129 studies reviewed, 59 employed a people perspective and almost without exception focused solely on the effects of employee ownership on employee behavior and attitudes. Turnover (intentions), commitment, job satisfaction, motivation, and absenteeism are the most commonly researched employee behaviors and attitudes. The remaining 70 studies employed a financial perspective and focused on the effects of employee ownership on the financial performance and productivity of companies.

Examples of commonly used financial performance measures are: profit margins, return on assets, and Tobin's Q. Value added per employee and sales per employee are examples of commonly used productivity measures.

By far the majority (87, or 67.4 percent) of studies found clear favorable results relating to employee ownership: 39 out of 59 studies with a people perspective, 48 out of 70 studies with a financial perspective. The findings of 14 studies (10.9 percent; 8 with a people perspective, 6 with a financial perspective) could straightforwardly be called negative. This leaves 28 studies (21.7 percent) that found no significant associations with employee ownership, or with results that were simply inconclusive (12 with a people perspective, 16 with a financial perspective).

In sum, two-thirds of employee ownership studies found favorable effects relating to employee ownership, while one-third did not. One-tenth of all studies found negative effects. However, positive effects do not appear to come about automatically (Conte and Svejnar, 1990; Kruse, 2002; Kruse and Blasi, 1995; Sesil et al., 2001). Kaarsemaker (2006) concluded that “the state of affairs is such that scholars and practitioners are still largely in the dark with regard to the specific conditions under which employee ownership yields favorable effects.”

Kaarsemaker and Poutsma (2006) in their review of employee ownership and SHRM literature stated:

One of the reasons for the relative weakness of the results from empirical research on the consequences of employee ownership is that, as yet, the theory behind many of the studies on the effects of employee ownership has been underdeveloped. In particular, no research has been done on
comprehensive models of employee ownership and the broader HRM system.

Despite a lack of comprehensive models, several researchers have focused on combinations of employee ownership with specific HRM practices, predominantly participation in decision-making, and a number of notable findings were documented. The importance of the workforce philosophy, or management’s commitment to employee ownership, for example, is demonstrated by a number of studies (e.g. Culpepper et al., 2004; Gamble et al., 2002; Klein, 1987; Klein and Hall, 1988; Long, 1982; Rosen et al., 1986). Also, several HRM practices have been included in the research with differing results. This mostly relates to forms of participation in decision-making, but also to, for example, information-sharing (e.g. Freeman et al., 2004; French and Rosenstein, 1984; Kalmi, 2002), and profit-sharing (e.g. Brown et al., 1999; Freeman et al., 2004; Wilson and Peel, 1990). One study (Freeman et al., 2004) included a bundle of HRM practices as one variable, an ‘HRM index’.

Overall, however, the theory behind most of these studies lacks a sophisticated explanation of why specific practices would be important in relation to employee ownership, and what would be the added value of employee ownership, or what would be the added value of combining these other HRM practices with employee ownership. This lack of theoretical sophistication is reflected in the relatively weak empirical findings. (Kaarsemaker and Poutsma, 2006)

2.3 Gaps in Employee Ownership Literature

In conclusion, there are four main gaps and potential contributions in the employee ownership literature:

2.3.1 Contingency Theory

The specific conditions under which employee ownership yields favorable effects are largely unknown. A contingency theory, as opposed to a universal approach, is needed to answer under what conditions employee ownership improves firm performance.
2.3.2 Causal Mechanisms

The theory of the underlying causal mechanisms of employee ownership effects is underdeveloped. One needs to build a model that captures the causal mechanisms between HRM practices and firm performance.

2.3.3 Systems Approach

The relationships of employee ownership with other HRM practices and several contingencies are too “complex and intertwined” (Poole and Jenkins 1990) to assume a simple isolated relationship with participation in decision-making or some other single factor or number of factors. One needs an integrated systems approach that connects the isolated linkages as a whole.

2.3.4 Dynamic Analysis

Most of the empirical studies on employee ownership effects are static in the sense that they do not take timing into consideration. The field of employee ownership would benefit from a dynamic analysis of how different timing (span across the industry lifecycle) of employee ownership policies affects employee behavior and firm performance over time.
3. METHODOLOGICAL CHALLENGES IN STRATEGIC HUMAN RESOURCE MANAGEMENT AND HIGH PERFORMANCE WORK SYSTEM

This chapter reviews the field of Strategic Human Resource Management (SHRM) and High Performance Work Systems (HPWS). SHRM and HPWS aim to study two broad questions: (1) how do human resource management (HRM) systems influence firm performance? and (2) What determines the form of HRM systems? The first question can be separated into two types of studies aiming to understand: (1A) the HRM-employee behavior (productivity, turnover) link; and (1B) the HRM-performance link (see Figure 3.1).

On the first question much progress has already been made. MacDuffie (1995) found in his sample of worldwide auto assembly plants that HR practices tended to “bundle” productivity and quality. Huselid (1995) found that HPWS have an economically and statistically significant impact on both intermediate employee outcomes (turnover and productivity) as well as short- and long-term measures of corporate financial performance. Delery and Doty (1996) found that among a sample of banks, significant relationships occurred between HR practices and accounting profits. Youndt et al. (1996) found that certain combinations of HR practices were related to operational performance indicators among their sample of manufacturing firms. Guthrie (2001) surveyed corporations in New Zealand and found their HR practices were related to turnover and profitability.
While these and many other studies (see Combs et al. 2006 for a meta-analysis) confirm the positive relationships between HRM and performance, much less is known about the causal mechanisms linking work systems and performance (Wright et al., 2001). The failure to capture the causal mechanisms is in part due to the methodological challenges in the field (Ichniowski et al. 1996, Guest 1997, Becker and Huselid 1998, Huselid and Becker 1996, Gerhart et al. 2000, Becker and Huselid 2006). This chapter presents a review and critique of the SHRM/HPWS literature and identifies five methodological challenges in the field. The next chapter then addresses how the system dynamics simulation method could contribute to the field of SHRM/HPWS by addressing its methodological challenges.

3.1 Lack of Causal Process Modeling

The majority of SHRM/HPWS empirical work relies on survey-based multivariate regression analysis to estimate the relationship between HRM systems and performance. This vein of research is epitomized in Huselid and Becker’s statement: “based on four national surveys and observations on more than 2000 firms, our judgment is that the effect of a one standard deviation change in the HR system is 10-20% of a firm’s market value” (Huselid and Becker 2000, p. 851). One limitation of such an approach is the correlation observation of what might happen between two variables; the approach lacks a causal explanation of why correlation happens. To explain why things happen, we need to go beyond regression analysis and build causal process theory to explain the underlying mechanisms. “If a regression tells us about a relation between two variables – for instance, if you wind a watch, it will keep running – mechanisms pry the back off the watch and show how” (Davis and Marquis 2006). Andersen et al. (2006) in their call for understanding mechanisms in organizational research state that

Mechanisms allow us to see beyond the surface-level description of a phenomenon. If we observe two variables, Y and X and some association between them, we know little more than that X and Y are correlated. Does X cause Y? Does Y cause X? Or are we observing a spurious correlation between the two brought about by a third unobserved variable, Z? Answering this question requires one to move beyond studying the X-Y relationship to addressing the questions of why and how the relationship occurs. In other words, what is the process underlying the relationship?
For the field of SHRM to move forward, we need to build process theory to explain the relationships we observe. This very need has led Becker and Huselid (2006) to call for the opening of the "black box" of HRM-performance links: "A clearer articulation of the "black box" between HR and firm performance is the most pressing theoretical and empirical challenge in the SHRM literature."

To open the black box, one needs to first propose the underlying causal mechanism and then conduct empirical testing. On the theoretical front, Becker and Huselid (1998) provide a model of the HR-shareholder value relationship (Figure 3.2). This model provides a causal path of how HRM influences firm performance.

**Figure 3.2: A model of the HR-shareholder value relationship (Becker and Huselid 1998)**

Another approach is to apply the balanced score card framework to the HR sector and propose the causal linkages among the HR system, workforce, business process, customer and financial performance (Figure 3.3). This line of research offers a promising path to open the black box (Becker et al. 2001, Beatty et al. 2003, Huselid et al. 2005).
The empirical testing of causal mechanisms lags significantly behind the theoretical front. Despite the necessity of considering mediating links for understanding the impact of HR practices on firm performance (Becker and Gerhart 1996), prior studies have rarely specified or tested specific HR practices or the underlying organizational capabilities for establishing these links (Wright et al. 2001). Collins and Smith (2006) are among the first to empirically test the mediating factors between HRM and performance. They proposed a model linking commitment-based HR practices to firm performance (Figure 3.4).

Through a field study of 136 technology companies, Collins and Smith found that commitment-based HR practices were positively related to the organizational social
climates of trust, cooperation, and shared codes and language. In turn, these measures of a firm’s social climate were related to the firm’s capability to exchange and combine knowledge, a relationship that predicted firm revenue from new products and services and firm sales growth. They argue that researchers “must explore mediating firm capabilities to fully understand the role of HR practices on firm performance” (Collins and Smith 2006, p. 553).

Collins and Smith expressed surprise at discovering that relationships between the social climate variables were only partially mediated through employee knowledge exchange and combination. They concluded “it is likely that climates of trust, cooperation, and shared codes and language are strategic variables yielding other firm-level performance benefits beyond knowledge creation” (p. 555). This hints at the other causal paths in the HRM-performance black box. As I will argue in later sections, system dynamics is particularly well suited for modeling the causal mechanism of how HR practices influence organizational performance, thus helping to open this “black box”.

### 3.2 Recursive Model

Another common concern in the SHRM/HPWS empirical literature is “the caveat that the positive cross-sectional HR-firm performance relationship is, in part, influenced by mutual causation or simultaneity bias” (Becker and Huselid 2006). Most of the empirical work in SHRM/HPWS adopts the recursive model assumption for examining the HRM-performance link. Recursive models meet the following conditions: 1) Models are hierarchical. All causal effects in the model are unidirectional in nature, i.e., no two variables in the model are reciprocally related, either directly or indirectly. 2) All pairs of error (or disturbance) terms in the model are assumed to be uncorrelated (Barry 1984).

An advantage of recursive models is that they are easy to estimate. All recursive models are identified. OLS regression can be used to obtain unbiased estimates of the model’s coefficients. If a recursive model is employed when the assumptions required are violated and if OLS regression is used to estimate the coefficients of the model, the resulting estimates will be biased and inconsistent and therefore give an inaccurate assessment of
the nature of the magnitude of the causal effects. Thus, unless one is convinced that (1) causation among the variables is strictly unidirectional, and (2) the factors constituting the error terms in the model are fundamentally different for each equation, recursive models should not be used; more realistic non-recursive models should be estimated instead (Barry 1984).

Unfortunately, in many situations the assumptions of recursive models do not in fact hold. Take Huselid (1995), one of the most highly cited works in this area, as an example. Huselid assumes a recursive model of HRM-performance link by regressing:

\[ \text{Firm Performance} = f(\text{HR Strategy, Firm Employment, Capital Intensity, Unionization, Sales Growth, R&D intensity}) \]

The inherent assumption is that HR strategy influences firm performance unidirectionally and that HR managers do not consider past performance when they decide on HRM. This seems unrealistic. What is missing in the past recursive model studies is the concept of dual causation, or feedback loops (in system dynamics terms). A more realistic model recognizes the possibility of dual causation from HRM to performance and from performance to HRM in a feedback system.

Guest et al. (2003) and Wright et al. (2005) are among the first to study dual causation. They rely on analyses of HR measures at Time T and measures of firm performance at Times T+1 and T-1. They argue that the absence of a HR effect on Performance at T+1, controlling for Performance at T-1, calls into question any interpretation that HR’s effect in prior cross-sectional research is a causal relationship. Guest et al. (2003) and Wright et al. (2005) have done the field a service by raising the right question of dual causation, but their empirical tests fall short of tackling the complexity of the problem. Aside from relying on pre- and post-performance measures to capture dual causation, Wright et al. (2005) limited their analysis to simple and partial correlations. Although their reliance on data from a single firm arguably should reduce the variance in the firm performance measures, the simple correlation between HR practices and profitability never explains more than 10% of the variance in their profitability measure (Table 4, p. 429). By relying
on simple and partial correlations, they fail to provide an explicit causal explanation of how past performance influences HRM.

One problem with this literature is that it is mainly based on regression analysis from survey data. To understand how performance feeds back to HRM, we need to have a more elaborate theory of how HRM systems are determined, followed by empirical testing. To have a better sense of how HR managers make decisions on what HRM to adopt and why, we need to rely on qualitative methods to elicit the mental models of HR managers, such as what information cues they use to decide whether to adopt HPWS or not. Some HR managers argue that more performance leads to more HPWS because more financial resources are available. Others argue that HPWS is introduced precisely when performance is low in order to improve it. Other hypotheses also likely exist. We need more in-depth qualitative fieldwork to understand what is really going on in HR managers’ minds. Ichniowski et al. (1996) concluded their seminar review paper with a similar statement:

> To complement these quantitative studies, we will always need detailed qualitative studies that observe hard-to-quantify data and shed light on crucial details of how to implement innovative practices successfully - in other words, to get into the ‘black box’ that explains how and why people perform as they do. Ultimately, results will only be convincing if they show up in both qualitative and quantitative studies.

I will argue in the later section that system dynamics (SD), with qualitative grounded theory building as a core method for building the model, is well suited to address this issue. I will also point out that the concept of feedback is central to SD models, where the underlying causal mechanism of how dual causation could occur in the HRM-performance relationship could be captured.

### 3.3 Concurrent Measures

Timing of data collection on the dependent and independent variables is also another issue in the SHRM/HPWS empirical literature. Wright et al. (2005) conducted a literature review of sixty-eight empirical studies examining the relationship between multiple HR practices and performance. They categorized the studies into four types of research
design. First, “post-predictive” are studies measuring HR practices after the performance period, resulting in actually “predicting” past performance. Such designs ask respondents for their firm’s current HR practices but measures their past performance (i.e., performance up until the point of the response), presenting a logical inconsistency for arguing that HR practices cause performance. Second, “retrospective” studies ask respondents to recall HR practices existing before the performance period. The primary problem here is that key informants may not be able to accurately recall sets of HR practices used in previous years due to inappropriate rationalizations, oversimplifications, faulty post hoc attributions and simple lapses of memory (Golden 1992, Huber and Power 1985). Third, “contemporaneous” design collects contemporaneous HR practice and performance data. Fourth, “predictive” design assesses how the HR practices at one point in time relate to the subsequent firm performance at a later period.

Post-predictive design is the weakest form among the four types of research design for explaining whether HR practices cause performance. Unfortunately, Wright et al. (2005) found the vast majority of studies (50 out of the 70 designs) used a “post-predictive” design, and stated that “it is not surprising given the relative ease of data collection, but it does make one wonder how such studies can legitimately suggest that HR practices ‘cause’ performance.” Six studies used a retrospective and four used a contemporaneous design. Predictive design, the strongest of the four for arguing a causal relationship, was used in only 10 studies. This is a disturbing summary of the state of empirical studies in SHRM/HPWS and seriously highlights the importance of timing in our data collection.

3.4 Linear Assumption

Another issue in the SHRM/HPWS empirical literature is the linear assumption in the OLS model specification. A typical regression takes some variant of the form:

\[
\text{Organizational Performance} = a + b*\text{HPWS} + c*\text{Control Variables} + \text{Error Term}
\]

The assumption is that there is a linear relationship between HPWS and performance. Huselid (1995), for example, found “a one-standard-deviation increase in [HPWS]
associated with a relative 7.05 percent decrease in turnover and, on a per employee basis, $27,044 more in sales and $18,641 and $3,814 more in market value and profits, respectively” (p. 667). The problem with such findings is it assumes the same incremental impact regardless of the current HRM level of sophistication, which is most likely unrealistic. One would expect the link between HRM and performance to be nonlinear. Becker and Huselid (1998 p. 75) find a nonlinear relationship between quintile changes in HR architecture sophistication and shareholder equity (Figure 3.5). They reason:

The first of these strategies, where the firm improves their HRM system to the point where they are ‘part of the pack,’ has a high payoff is because it represents a minimum threshold. Beyond that point (i.e. plus or minus one standard deviation around the mean), changes in the HRM system have much smaller effects. At this point firms are competitive, but they have not optimized their HRM system to the point where they have begun to enjoy a sustained competitive advantage. Firms only begin to build that competitive advantage when they have moved at least one standard deviation above the mean, or the upper 16% of the distribution (Becker and Huselid 1998)

Figure 3.5: Dollar Change in Market Value per Employee

Source: Huselid and Becker (1995)
Other hypotheses could emerge, however; by explicitly modeling the causal path of HRM on performance in a system dynamics model, one could simulate the incremental impact of HRM on performance at different HRM levels. Such a relationship will most likely be nonlinear as one causal loop dominates another at different time periods (Sterman 2000). This depiction, as in Figure 3.3, enables deeper understanding of the underlying causes giving rise to nonlinear relationships.

### 3.5 Omitted Variable Bias

Omitted variable bias occurs if an omitted variable is correlated with both the HPWS variable and the dependent variable. The direction and magnitude of that bias depend on the direction and magnitude of those correlations. For instance, organizations adopting HPWS may have both higher-quality and more productive employees. To what extent is improved performance due to HPWS alone? The higher the effect of the omitted employee quality on performance, the more upwardly biased is the HPWS coefficient, as it “absorbs” the omitted effect.

If the omitted variables are relatively stable over the study period, then the use of longitudinal data examining whether changes in HPWS predict changes in performance will be better able to control for the omitted variables. If the omitted variables are not stable, however, then the only remedy is to identify them from theory, measure them, and attempt to control them statistically (Ichniowski et al. 1996). I argue that another alternative is to explicitly model the causal path of the mediating and direct effects of these variables in the HPWS-performance link by using system dynamics. The more one is able to capture the relevant variables and to structure them in the model boundary, the more one is able to isolate the specific impact of HPWS on performance.
PART II: METHOD

4. SYSTEM DYNAMICS METHOD

4.1 Why System Dynamics?

To develop theory of the causal mechanism from HPWS to performance, one needs to go beyond survey-based regression analysis and employ other methods such as process theory building and simulation. Davis et al. (2007) call for developing theory through simulation methods:

Simulation enables the elaboration of rough, basic (or what we term simple) theory that is often derived from inductive cases or formal modeling into logically precise and comprehensive theory. This theory can then be effectively examined further using deductive logic and empirical evidence. Simulation is particularly useful when the theoretical focus is longitudinal, nonlinear, or processual, or when empirical data are challenging to obtain. (Davis et al. 2007)

With this in mind, I take a simulation approach that is quite different from those present in the existing literature. It is difficult to test hypotheses to explain the impact of various forms of employee ownership because it is not possible to conduct experiments with real organizations. Models provide a means to explore the consequences of alternative policies and environmental conditions in target settings. Capturing complex interactions among various employee ownership policies in a model requires a methodology that can represent the physical and institutional structure of a firm and its markets, that can portray the decision rules of the actors in the system, and that can deal with multiple levels of analysis (product development, sales, human resource, market, the stock market) and link them in causal feedback systems (Sterman, Repenning and Kofman 1997). For these reasons I choose to use the system dynamics method to develop the theory and build the model.

System dynamics (SD) is a formal modeling and simulation method designed to explain dynamic behavior generated from underlying causal structures characterized by feedbacks, nonlinearity and time delays (Forrester 1961, Sterman 2000). SD starts with a
problem definition illustrated in a behavior-over-time graph, such as “why does firm performance vary over time, given a set of HPWS?” The assumption that “structure determines behavior” is core to SD methodology. To understand the dynamic effects of HPWS on performance, one maps out the underlying causal structure using qualitative grounded theory building methods through ethnography, interview, case study and archival data. That structure is represented in a set of reinforcing and balancing feedback loops, called a Causal Loop Diagram, capturing dynamic hypotheses responsible for the problem. By explicitly modeling the causal paths from HPWS to performance, and simulating the dynamic behavior of performance under various HPWS scenarios, one is able to generate and test a set of causal theories explaining the impact of HPWS on performance.

SD has been used to study the behavior of the firm (e.g., Forrester 1961; Lyneis 1980; Morecroft 1985; Sterman, Repenning and Kofman 1997; Oliva, Sterman and Giese 2003), organizational dynamics (Repenning and Sterman 2002, Repenning 2001, 2002, Rudolph and Repenning 2002, Sastry 1997) and managerial decision making (Sterman 1989a, 1989b; Paich and Sterman 1993).

4.2 Benefits of System Dynamics

Table 4.1 summarizes how system dynamics could help address the current methodological challenges in SHRM that cause the failure to capture the causal mechanisms and paths linking work systems and performance.

<table>
<thead>
<tr>
<th>SHRM Methodological Challenge</th>
<th>System Dynamics Approach</th>
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<tbody>
<tr>
<td>1 Lack of causal process model</td>
<td>Causal process model</td>
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<td>2 Recursive assumption</td>
<td>Feedback loops</td>
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<tr>
<td>3 Linear assumption</td>
<td>Nonlinear dynamics</td>
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<tr>
<td>4 Timing of data collection</td>
<td>Time delay</td>
</tr>
<tr>
<td>5 Omitted variable bias</td>
<td>Mediating and moderating causal paths</td>
</tr>
</tbody>
</table>
4.2.1 Causal Process Model

With regard to the black box criticism, a SD model provides an explicit causal theory of why and under what conditions various HPWS improve performance. Such a formal model building process helps us better understand the causal logics proposed in the existing literature as we attempt to formalize them. It also allows us to test the internal consistency of the proposed theories and to identify potential gaps for further development similar to Sastry’s (1997) SD model of the punctuated equilibrium theory.

4.2.2 Feedback Loops

To turn the existing recursive models into non-recursive ones, SD uses various reinforcing and balancing feedback loops to capture the underlying structures. Such feedback loops are grounded in the actual processes discovered through prior literature and fieldwork research. SD allows one to address the dual causation or simultaneity issue raised by Wright et al. (2005). For example, SD could model explicitly how performance influences HR managers’ decisions to adopt HR practices and close the HRM-performance-HRM loop. Through partial model testing (Homer 1983, Morecroft 1985), one is able to test the intended rationality of HR managers and shed light on the question: if HPWS have positive results, why are they so slow to diffuse within and across organizations?

4.2.3 Nonlinear Dynamics

Instead of assuming linearity, SD is rooted in the theory of nonlinear dynamics and explicitly models nonlinear relationships among variables. One is able to study tipping dynamics, such as the reverse effect of stock options when they go underwater, using loop dominance analysis (Richardson 1984, Sterman 2000). Also, through simulation analysis, one could not only estimate the direction of a HPWS effect, but also its magnitude over time at various levels of sophistication.

4.2.4 Time Delays
To address issues of timing of data collection, SD explicitly models time delays in physical, administrative and mental processes through the construct of stocks and flows (Sterman 2000). For example, SD is able to capture the time it takes for training to have an impact on productivity and the time it takes to make HR decisions. Both delays help explain why some companies fail to adopt HPWS after a short experiment, and why some go through the worse-before-better performance after adopting HPWS successfully (Pil and MacDuffie 1996).

4.2.5 Mediating and Moderating Causal Paths

SD addresses the omitted variable bias by modeling how individual HR practices influence performance through various mediating causal paths. It also captures the moderating effects of how other factors such as business processes and market conditions influence performance. By controlling for these factors, one is able to isolate the effects of HPWS as much as possible.

These are clearly some contributions SD can make to the field of SHRM/HPWS and there could be more, as SD is increasingly adopted as a legitimate method. Like any other method, there are limitations to the SD method. Further research is needed to identify under what conditions SD is a useful method in SHRM/HPWS and how SD could be combined with regression analysis to help open the black box. This dissertation serves as one first step.

4.3 How Can System Dynamics Contribute to Strategic Human Resource Management?

This section proposes four generic steps of how SD can contribute to SHRM/HPWS. Their sequential process is illustrated in Figure 4.1.
1. **System Dynamics Model Building**: to open the black box generating the correlation observations, system dynamics is used to build a causal process model of how HR practices, through various causal paths, lead to firm performance. The model is constructed based on existing theoretical and empirical findings in the literature. This process allows one to clarify and test the causal logic of existing theories by turning verbal theories into formal mathematical models. If we find incompleteness or inconsistency, it allows us to identify the gap and to propose new theories. Sastry’s (1997) formal model of punctuated equilibrium helps identify gaps in the original theory and provides a refined theory. Similar approaches could be applied to SHRM/HPWS.

When there are gaps in the causal mechanisms found in the existing literature, one can conduct qualitative field research to map out the actual causal process. This engages the grounded theory building approach (Glaser and Strauss 1967) to generate new theory when the existing theory is unclear. Such mixed methods among quantitative regression analysis, qualitative field research and simulation methods allow the model to draw on the strength of each method to improve our understanding of the underlying causal mechanisms.
2. **Simulation Analysis:** Once a causal model is built with a set of differential equations characterizing the causal relationships among variables, one can conduct simulation analysis by changing the independent variable that we care about, such as the profit sharing percentage. One can test how different levels of profit sharing in turn influence firm performance over time. Simulation data is generated to show the relationship between profit sharing and performance.

3. **Dynamic Theory Building:** If the simulated data confirms the previous empirical findings, one gains confidence that the model may have captured the underlying causal mechanism between profit sharing and firm performance. The model contributes to the field by providing a dynamic theory of how profit sharing leads to higher (or lower) performance.

4. **Regression Analysis:** If the simulated data does not confirm the empirical finding, this informs us that either something is missing in the model or the previous regression model was mis-specified. If one is reasonably confident about the model, one can specify the regression equation on the real data based on the causal model and collect additional data if needed. The new regression analysis can test the dynamic hypothesis from step 3 and provide further empirical evidence.

   It may well be that the system dynamics model is mis-specified. Perhaps a function is not correctly estimated, or a feedback loop is missing from the model. One can conduct further field research and data collection to revise the system dynamics model and propose a new dynamic theory.

   This process not only allows us to identify gaps in the existing theory, but also enables the generation of new theories that can then be tested empirically using regression analysis. The iterative process goes on (as illustrated by the circular loop above) between empirical testing and theory building. As a result, our understanding of the underlying causal mechanisms improves over time.
5. METHODS OF DISSERTATION RESEARCH

This chapter presents the methods and data sources used for building the model in this dissertation. It includes mixed quantitative, qualitative and simulation methods.

5.1 Method for Model Building

To study the causal mechanisms of how HR practices influence firm performance, I develop a system dynamics model of a clean technology startup company with a detailed HPWS. The model captures how various compensation and HR practices influence the employee behaviors that drive business processes. The model further expresses how those business processes interact with market conditions and generates firm performance in a dynamic feedback system.

The model is grounded on prior literature and multiple data sources shown in Figure 5.1. There are three core structures in the model: a clean technology startup structure (business processes and customers), a HPWS, and an accounting and corporate finance structure.
5.1.1 Clean Technology Startup Model

The core clean technology startup structure is based on Miller’s (2007) dissertation “New Venture Commercialization of Clean Energy Technologies.” My contribution is refining the Miller model and adding a detailed HPWS, a detailed corporate finance and accounting system and a multiple competitor structure.

5.1.2 High Performance Work System

The detailed HPWS captures a set of “hard” financial compensation policies such as salary, stock grants, stock options and profit sharing along with “soft” HR practices such as employee participation, training, coaching and job security. To build the HRM structure in the model, I perform a thorough literature review on the existing theoretical and empirical findings in SHRM, HPWS and Employee Ownership and then transform the proposed relationships into a formal differential equation model. This process
enables me to better understand the causal logics proposed in the current literature as I formalize them.

In addition to the HR literature, the model is also grounded on prior system dynamics literature on human resource management thanks to system dynamics' rich history in modeling workforce flow and management (Sterman 2000).

5.1.3 Accounting and Corporate Finance Structure

To the accounting and corporate finance structure I add a detailed balance sheet, income statement, cash flow, firm valuation and shares outstanding, ownership structure, government grants and venture capital structure. To ground my model, I draw on a prior system dynamics model (Oliva, Sterman and Giese 2003) and on existing accounting and corporate finance literature and textbooks. To clarify some internal firm processes, I conduct interviews with scholars, professionals and managers to ensure the proposed structure and behavior is robust in their experience.

5.2 Method for Model Estimation and Calibration

To ensure the model is grounded in rigorous empirical evidence, I conduct both quantitative regression analysis for estimating the functional forms and qualitative field research for calibrating the model of a startup company.

5.2.1 Regression Estimation using the NBER Shared Capitalism Dataset

One of the main empirical contributions of this dissertation is the estimation of various employee ownership effects. As understanding employee ownership effects is the main purpose of this dissertation, I estimated the non-linear functional forms of various employee ownership effects. I was able to collaborate with Professors Joseph Blasi and Douglas Kruse from Rutgers University to run regression estimates using their National Bureau of Economic Research (NBER) Shared Capitalism dataset (Kruse, Freeman and
The NBER survey administered 80 to 100 questions to 41,206 employees in fourteen firms at 323 work sites that had some shared capitalism modes of compensation. This data set is the largest one ever conducted on workers in shared capitalism firms. The 80 to 100 survey questions cover most of the variables found in a typical HPWS with shared capitalism modes of compensation, making it the best source available for estimating the employee ownership effects.

5.2.2 Field Research of a Clean Technology Startup Company

To calibrate the model, I conducted interviews and collected archival data on an early-stage clean technology startup company that produces energy efficiency systems for commercial and industrial buildings. Given the inherent limitation of an early-stage startup – there is no later-stage time-series data – the company data was used to parameterize the initial conditions of the model. I interviewed the executives to identify their decision-making rules for pricing, financing, human resource and compensation policies and their projections for business performance. The reasons for modeling a startup company are stated in Section 1.3.

5.2.3 Base Case Validation

While the model cannot perform a historical fit analysis as there is no time-series data available, the stylized pattern of behavior shown in the base case scenario is consistent with the entrepreneurship literature: the “valley of death” dynamics (the period of time from when a startup firm receives an initial capital contribution to when it begins generating revenues and a positive cash flow); the need for several rounds of VC financing in a long product development and sales cycle industry; the product life cycle of going from infancy, growth, maturity to decline; and the strategic shifting from product development at the early stage to a sales-focused strategy in the growth stage and service model at the mature and decline stage. Future work can be done to calibrate the model to a startup with a long enough time-series data set.

1 I would like to thank Professors Joseph Blasi and Douglas Kruse of Rutgers University for their generosity in sharing their valuable data with me.
5.3 Method for Model Analysis

5.3.1 Policy Analysis

I conducted simulation analyses to study how various combinations of salary, stock grants, stock options, profit sharing schemes and employee participation efforts influence employee behavior and firm performance over time. The simulation results offer insights into the dynamic effects of shared capitalism policies and allow one to tease out the direct versus mediating effects through various causal paths in the system. Eleven propositions addressing the research question – under what conditions do shared capitalism policies improve firm performance? – are proposed. Several thresholds are identified to explain the tipping dynamics observed in the simulated employee ownership effects on firm performance.

5.3.2 Sensitivity Analysis

To ensure the robustness of model analysis, I conducted two sensitivity analyses. The first studies the extent to which firm performance is sensitive to the effect of financial compensation on job satisfaction. The second sensitivity analysis focuses on uncertainty in competitive pressure and tests how sensitive firm performance is to a sudden decrease in sales productivity.
PART III: MODEL DESCRIPTION

6. MODEL OVERVIEW

This chapter provides a high-level overview of the model. Detailed model formulations are explained in Chapter 7.

6.1 Model Framework and Boundary

Figure 6.1 illustrates the model framework. The inner four thick boxes capture the internal processes within a firm. The outer boxes are leverage points or strategies managers can employ to potentially influence the processes. This model offers a generic process theory of the firm and the role of managers. The four internal processes are employee behaviors, business processes, market conditions and financial performance. They resemble the balanced scorecard framework: learning and growth, business processes, customers and finance (Kaplan and Norton 1992, 1996a, 1996b). What is different about this framework is its transformation of the traditional balanced scorecard into a dynamic feedback framework with explicit causal linkages connecting across the four quadrants; system dynamics is particularly suited to developing dynamic balanced scorecards (Kaplan and Norton 1996a, Akkermans and Oorschot 2002) using causal feedback modeling. Given that this dissertation focuses on the internal processes of a startup company, this model helps make the framework more explicit and can be used to guide strategic planning for a startup company.

The model’s inner quadrants capture the various reinforcing growth loops (Sterman 2000, Chapter 10) propelling a company as well as capturing the balancing loops that constrain growth. In particular, the model captures how various HR policies (hiring, selection, training, salary, stock grants, stock options and profit sharing) drive employee attitudes and behaviors (financial compensation, psychological ownership, burnout, Job satisfaction, employee quality, turnover, experience, learning, productivity, and work effort); how employee behaviors drive business processes (product development, customer service, sales, and marketing); and how business processes interact with market
conditions (industry demand, sales cycle, competition, and government regulation) to generate firm performance (sales, revenue, cost, profit, stock price, ownership share and net worth). By knowing both the internal firm processes and the managerial policies, one is able to identify the high leverage points (Sterman 2000) for managers’ intervention.

Given that the focus of this dissertation is on the employee ownership effects, I will analyze various shared capitalism HR policies (located in the lower left-hand corner), while holding the business strategy, exogenous conditions and funding strategy constant in Chapter 11.

Figure 6.1: Overall Model Framework
Figure 6.2 shows the model boundary. The four quadrants of firm processes – human resources, business processes, customers and finance – are endogenously determined. Inside each box are the model subsectors. Decision rules for compensation policies are exogenous, because the purpose of the model is to study how various shared capitalism policies influence internal firm processes and performance. Excluded from the model are tax regulation of specific employee ownership plans, corporate governance, disaggregated policy recipients, unions, labor market, venture capital control, debt financing and multiple startups.

Figure 6.2: Model Boundary
6.2 Firm Structure

While the model framework provides a high-level overview of the four main sectors in the model and their corresponding strategies, it does not capture the specific causal linkages among them. Figure 6.3 shows a more detailed causal loop diagram of key variables in the firm structure. Causal loop diagrams capture causal linkages among variables in a set of reinforcing and balancing feedback loops (Sterman 2000). The red variables are key managerial decision variables and the blue variables are key performance indicators. To specify model structure and the decision rules for the actors I drew upon established system dynamics models of the firm (e.g., Forrester 1961; Lyneis 1980; Morecroft 1985; Sterman, Repenning and Kofman 1997; Oliva, Sterman and Giese 2003) and experimental studies of managerial decision making (Sterman 1989a, 1989b; Paich and Sterman 1993).
Arrows represent a causal direction moving from the cause (e.g., product feature) to the effect (e.g., unit cost). Signs ('+' or '-') at arrow heads indicate the polarity of relationships: a '+' denotes that an increase in the independent variable causes the dependent variable to increase, ceteris paribus (and a decrease causes a decrease). Similarly, '-' indicates that an increase in the independent variable causes the dependent variable to decrease (e.g., an increase in product feature causes a decrease in unit cost). The loop identifier R indicates a positive (Reinforcing) feedback and B denotes a negative (Balancing) feedback loop (Sterman 2000).
6.3 Model Sectors

Table 6.1 shows a list of model sectors. There are four main sectors in the model: market, product development, HPWS, and accounting and corporate finance. Each sector has several sub-sectors that detail the specific internal processes. The full model documentation is listed in the appendix.

Table 6.1: Model Sectors

<table>
<thead>
<tr>
<th>Market</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Five-stage sale chain from potential customers to adopters</td>
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<td></td>
<td>Firm attractiveness</td>
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<td></td>
<td>Pricing</td>
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<td></td>
<td>Brand equity</td>
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<td>Competition: incumbent vs. startup</td>
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<th>Product Development</th>
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<td>Product development chain</td>
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<td></td>
<td>Unit costs</td>
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<td>Energy cost savings and customer payback period</td>
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<tr>
<th>Human Resource Management System</th>
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<tbody>
<tr>
<td></td>
<td>Employee chain: hiring, promotion, turnover and layoff</td>
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<tr>
<td></td>
<td>Employee types: engineers and sales force</td>
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<td></td>
<td>Employee experience: work experience, coaching and training</td>
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<td></td>
<td>Employee quality</td>
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<td></td>
<td>Compensation policies: salary, stock grants, stock options, profit sharing</td>
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<td></td>
<td>Employee participation</td>
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<td></td>
<td>Job satisfaction: compensation, psychological ownership, burnout, job security</td>
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<td>Employee productivity and work effort</td>
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<th>Accounting and Corporate Finance</th>
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<td></td>
<td>Accounting: balance sheet, income statement and cash flow</td>
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<td>Firm valuation and stock price</td>
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<td>Shares outstanding and ownership structure</td>
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<td>Government grants</td>
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<td></td>
<td>Venture capital</td>
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<td></td>
<td>Initial Public Offering</td>
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6.4  Causal Loop Diagram of High Performance Work System

Figure 6.4 illustrates some of the key reinforcing loops of the HPWS in the model. All the red variables are human resource policy variables; the green are job satisfaction drivers, and the blue are employee behaviors. Job satisfaction is modeled as the central mediating variable between various HR policies and employee behaviors.

The drivers of job satisfaction are financial compensation and other non-financial drivers such as job security, psychological ownership and burnout effects. Financial compensation includes salary, profit sharing and employee net worth; they are determined by the amount of stock options, stock grants accumulated and the current stock price. Psychological ownership is driven by the relative share of employee ownership and participation in the company. Employee ownership without participation has a limited effect, whereas combining both tends to produce positive results (Kruse, Freeman and Blasi 2010). Kaarsemaker (2006) found sixteen previous studies of the combination of employee ownership with participation in decision-making, or with an index of a number of people management practices: sixty-five percent produced favorable effects, while none produced negative effects.

Job satisfaction affects turnover, employee quality, employee productivity and work time. Higher job satisfaction lowers turnover rate and attracts better employee quality at recruiting. Employee productivity and work time increase as employees are willing to work harder when they are happier (R6 Work Harder).

Productivity effects are driven by employee experience, employee quality, job satisfaction and employee participation. Higher turnover decreases average employee experience as people leave with accumulated experience and the firm must hire rookies, which lowers the average employee experience level (R3 Turnover). Training increases employee experience by speeding up learning. Employee quality represents the initial quality of employees upon recruiting, such as education and skills levels. This quality variable captures the recruiting selection effect. A company with high job satisfaction tends to attract and select employees of higher quality, which raises productivity (R4...
Employee Quality). Higher job satisfaction can also directly increase productivity because people are happy with the work and the environment (R5 Happily Productive).

Effective work effort (separated into product development and sales efforts in the model) raises sales volume and net income. Higher net income leads to higher working capital and enables the firm to increase hiring. More hiring leads to more employees and greater effective work effort; this closes the R1 Hiring reinforcing loop. More hiring also leads to higher perception of job security, which increases job satisfaction and closes the R2 Job Security loop. The R7 Burnout loop captures the burnout effect from working overtime for too long.

In addition to the seven reinforcing loops, two additional loops close the feedback from firm performance to employee behavior. Higher net income leads to higher profit sharing, given a certain profit sharing percentage, which raises job satisfaction and productivity (R8 Profit Sharing). Higher net income also leads to higher stock price, which increases employee net worth, given the stock options and grants awarded in the past (R9 Employee Ownership).

It is important to note that the same reinforcing loop can work as either a virtuous or vicious cycle. R8 and R9 explain why profit sharing and employee ownership work well in virtuous cycles when the company is doing well. However, the same loops could turn into vicious cycles when profit is so low that stock options go under water, which lowers Job satisfaction and productivity and further reduces sales and profit, as witnessed during the dot.com bubble (Blasi, Kruse and Bernstein 2003).
Figure 6.4: Causal Loop Diagram of High Performance Work System

- Red: Human resource policies.
- Green: Job satisfaction drivers.
- Blue: Employee behavior indicators.
7. MODEL FORMULATION

This chapter explains key model sectors and formulations in detail. Full model documentation is listed in the appendix.

7.1 Employee Chain and Employee Experience

The human resource sector of the model is closely based on the labor supply chain introduced in Section 19.1 of Sterman (2000). Following Miller (2007), two types of employees are represented in the model: engineers and sales people. Engineers are considered to be employees with any technical or product development responsibilities, including customer and technical support, engineering or technology management and strategy positions, etc. Sales people are considered employees with any sales or marketing responsibilities, including sales or marketing management, production of materials, etc. Administrative employees (from the CEO to support personnel) are considered to be split up between the engineering and sales functions (e.g., a CEO who focuses on technical strategy and product development, but spends 25% of her time meeting with prospective customers, may be considered 75% an engineer and 25% a sales person).

Figure 7.1 shows the human resource structure. It takes into account the experience of the labor force, which is based on the labor co-flow structure detailed in Section 12.2 of Sterman (2000) and on Miller (2007). I expanded the single employee stock from the Miller model to stocks of rookies, experienced and former employees. The rookies are hired into the rookie employee stock through the Rookie Hire Rate. Rookies can either assimilate to experienced employees after a certain period in the firm, be laid off or voluntarily quit the firm. Similarly, the experienced employees can either stay in the firm, be laid off or choose to quit. The turnover rate (or voluntary quit rate) is driven by the effect of job satisfaction. The higher is the job satisfaction; the lower is the turnover rate. The actual functional form is estimated using the NBER shared capitalism dataset to be explained in Chapter 8.
The employee experience co-flow structure captures the number of years employees have been with the firm. Hiring rookies increases the total rookie fraction and lowers average employee experience. Layoff and turnover decrease employee experience as people leave the firm with the experience they have accumulated over the years. Experience gets accumulated as employees continue working in the firm (captured by the “Increase in On-the-Job Experience” inflows from Rookies and Experienced): the longer they stay working, the higher the experience. This is one reason why high voluntary turnover of experienced employees is costly to employee productivity and firm performance. The firm can also increase rookie experience through training and coaching (signified by the variable Learning per Hour for Rookies). Higher experience leads to higher employee productivity (to be explained later).
7.2 Work Effort and Productivity

Figure 7.2 shows the work effort and productivity structure. Effective work effort is the sum of rookie and experienced employee effective work effort. \([\text{vendor,department}]\) denotes the subscripts used in the model. The subscript range for vendor is incumbent and startup, meaning there is one startup company competing with the incumbent firm. The subscript range for department is engineer and sales, meaning there are two types of employees, engineers and sales force, in the model.

Effective Work Effort\([\text{vendor, department}]\)

\[
= \text{Rookie Effective Work Effort}[\text{vendor,department}] + \text{Experienced Effective Work Effort}[\text{vendor,department}]
\] (7.1)

Actual rookie work effort equals the number of rookie employees times the working hours per year net of work effort spent on employee participation (such as attending participation training and meetings). Effective rookie work effort is modeled as actual rookie work effort times total rookie productivity effects. Thus, when productivity effect \(= 1.05\), one person*hour/year of work effort can produce an effective work effort of 1.05 person*hour/year. That is 5% more work effort generated, given the same amount of actual work time. Experienced effective work effort has the same parallel formulation as the rookie effective work effort.

Rookie Effective Work Effort\([\text{vendor,department}]\)

\[
= (\text{Rookie Work Effort}[\text{vendor,department}] - \text{Rookie Participation Effort}[\text{vendor,department}]) \times \text{Total Rookie Productivity Effect}[\text{vendor,department}]
\] (7.2)

Rookie Work Effort\([\text{vendor, department}]\) = Rookie Employees\([\text{vendor,department}]\) * Working Hours per Year\([\text{vendor,department}]\)

(7.3)

There are four employee productivity effects: employee quality, work experience, job satisfaction and employee participation. The better the average employee quality upon hiring is, the higher the employee productivity. Employee quality captures the selection
Figure 7.2: Work Effort and Productivity Sector
of the initial quality of employees upon recruiting, such as education and skills levels. A firm with high job satisfaction tends to attract employees of higher quality, which raises productivity. Figure 7.3 shows the co-flow structure of employee quality, which is similar to the employee experience structure.

The effect of rookie employee experience on productivity is based on learning curve theory, referenced in Section 12.2 of Sterman (2000) and derived in Zangwill and Kantor (1998). The theory posits that productivity will rise by a given amount for every doubling of experience from an initial reference value.

Higher job satisfaction can also directly increase productivity because people are satisfied with the work and the environment. The functional form of the effect of job satisfaction on productivity is estimated using the NBER Shared Capitalism dataset explained in Chapter 8.

Total Rookie Productivity Effect[vendor,department] = \( \text{Effect of Rookie Employee Quality on Productivity[vendor,department]}\) * \( \text{Effect of Rookie Employee Experience on Productivity[vendor,department]}\) * \( \text{Effect of Job Satisfaction on Productivity[vendor,department]}\) * \( \text{Effect of Participation on Productivity[vendor,department]}\) \hspace{1cm} (7.4)

Effect of Rookie Employee Experience on Productivity[vendor,department] = \( (\text{Relative Rookie Experience[vendor,department]})^{\text{LN}(1 + \text{Employee Productivity Change Per Doubling of Experience[vendor,department]})/\text{LN}(2)}\) \hspace{1cm} (7.5)

Relative Rookie Experience[vendor,department] = \( \frac{\text{Average Rookie Experience[vendor,department]}}{\text{Reference Employee Experience [vendor,department]}} \) \hspace{1cm} (7.6)
7.3 Job Satisfaction

Job satisfaction is composed of reference job satisfaction plus four effects on job satisfaction: financial compensation, psychological ownership, burnout and layoff (Figure 7.4). Reference job satisfaction is 3 on a 1 to 4 scale used in the NBER Shared Capitalism data set to be explained later. The additive as opposed to multiplicative formulation is chosen because the four effects are arguably strongly separable: the impact of a change in any one input is the same no matter what values the other inputs have (Sterman 2000, p. 528). For example, when the effect of psychological ownership on job satisfaction is zero in the case of zero employee ownership, the effect of financial compensation on job satisfaction does not become zero as it would should one use a multiplicative formulation. The isolated effect of a 5% increase in pay on job satisfaction is assumed to be the same when there is zero employee ownership as when there is 10% employee ownership. The impact of different levels of employee ownership on job satisfaction is captured separately through the effect of psychological ownership on job satisfaction.

\[
\text{Job Satisfaction}[\text{vendor,department}] = \text{Reference Job Satisfaction}[\text{vendor,department}] + \text{Effect of Financial Compensation on Job Satisfaction}[\text{vendor,department}] + \text{Effect of Psychological Ownership on Job Satisfaction}[\text{vendor,department}] + \text{Effect of Burnout on Job Satisfaction}[\text{vendor,department}] + \text{Effect of Layoff on Job Satisfaction}[\text{vendor,department}] \tag{7.7}
\]
7.4 Psychological Ownership

Stock grants, stock options and profit sharing drive job satisfaction through two channels: financial compensation and psychological ownership effects. Psychological ownership effects (Pierce, Kostova and Dirks 2001, 2003) capture the satisfaction from the feeling of being an owner of a company *in addition to* its financial value. There are two psychological ownership effects: the employee ownership stake and profit sharing (Figure 7.5). Job satisfaction from the employee ownership stake captures the satisfaction derived from owning the stock of employee shares accumulated from the past. The employee ownership stake is the dollar value of average employee shares outstanding relative to the average salary. The more stock grants are awarded, the higher the number of vested employee shares. When the stock price increases as the firm starts to make a profit, the value of the employee ownership stake increases. Job satisfaction increases as employee net worth increases. Note that this captures the psychological effect from the accumulated “stock” of employee shares, which is different from the financial effect from the “inflow” of stock grants awarded each year. Job satisfaction increases when employees are awarded new stock grants in the current year; however, they also derive a psychological effect of feeling wealthy when the value of their vested stock grants increases. The functional forms of psychological effects from the employee ownership stake and profit sharing are estimated in Chapter 8.

Figure 7.5: Psychological Ownership Effects
Job Satisfaction from Psychological Ownership[vendor,department] = Job Satisfaction from Employee Ownership Stake[vendor,department] + Job Satisfaction from Profit Sharing[vendor,department] \hspace{1cm} (7.8)

Job Satisfaction from Employee Ownership Stake[vendor,department] = Function for Job Satisfaction from Employee Ownership(\text{Employee Ownership Stake Relative to Salary[vendor,department]/Reference Employee Ownership Stake Relative to Salary}) \hspace{1cm} (7.9)

Employee Ownership Stake Relative to Salary[vendor,department] = \text{Value of Average Employee Shares Outstanding[vendor,department]/Average Salary[vendor]} \hspace{1cm} (7.10)

Value of Average Employee Shares Outstanding[vendor,department] = \text{Average Employee Shares Outstanding[vendor,department]*Stock Price[vendor]} \hspace{1cm} (7.11)

Average Employee Shares Outstanding[vendor,department] = \text{Employee Shares [vendor,department]/Total Employees per Department [vendor,department]} \hspace{1cm} (7.12)

Employees experience psychological ownership when the firm is willing to share its profit with employees. It is modeled relative to one’s salary, to capture the psychological effect of comparing the bonus one receives relative to one’s salary level. Calculating the psychological effects on a relative basis provides a convenient normalization and is consistent with basic perception theory, which suggests that people evaluate rates of change on a proportional rather than absolute basis (Plous 1993). A bonus of $10,000 may mean more to an employee with a $50,000 salary (a 20% increase) than one with a $200,000 salary (a 5% increase). Note that this captures the psychological effect of profit sharing; the financial effect of the actual dollar amount of profit sharing is captured through the financial compensation effect in Equations 7.15 and 7.16 below.
Job Satisfaction from Profit Sharing[vendor,department] = Function for Job Satisfaction from Profit Sharing(Profit Sharing as Percentage of Salary[vendor,department]) \hspace{1cm} (7.13)

Profit Sharing as Percentage of Salary[vendor,department] = Expected Profit Sharing per Employee[vendor,department]/Average Salary[vendor] * 100 \hspace{1cm} (7.14)

7.5 **Financial Compensation**

The effect of financial compensation on job satisfaction captures the financial value of a shared capitalism mode of compensation (Figure 7.6). The expected present value of total compensation (composed of salary, stock grants, stock options and profit sharing) is calculated and then divided by the reference present value of total compensation. The functional form for the Effect of Financial Compensation on Job Satisfaction is non-linear. Its estimated function is explained in Chapter 8.

Effect of Financial Compensation on Job Satisfaction[vendor,department] = Function for Effect of Financial Compensation on Job Satisfaction (Expected Present Value of Total Compensation[vendor,department]/Reference Present Value of Total Compensation) \hspace{1cm} (7.15)

7.5.1 Expected Present Value of Salary

Expected present value of salary equals salary divided by the discount rate for total compensation. This assumes the employees value salary as perpetuity or a stream of equal payments of infinite horizon.

\[
\text{Expected Present Value of Salary}_{\text{vendor,department}} = \frac{\text{Salary}_{\text{vendor,department}}}{\text{Discount Rate for Total Compensation}_{\text{vendor}}} \tag{7.17}
\]

7.5.2 Discount Rate

Discount rate for total compensation assumes a normal discount rate to capture the time value of money plus a risk premium based on the probability of being laid off or of the firm failing. The hazard rate that the firm will fail or lay off its employees rises as perceived liquidity falls. For simplicity, I assume that the annual hazard rate of failure is a normal rate divided by perceived liquidity, that is, the hazard rises in inverse proportion to liquidity.

\[
\text{Discount Rate for Total Compensation}_{\text{vendor}} = \text{Normal Discount Rate for Compensation} + \text{Expected Layoff or Failure Hazard Rate}_{\text{vendor}} \tag{7.18}
\]

\[
\text{Expected Layoff or Failure Hazard Rate}_{\text{vendor}} = \frac{\text{Normal Layoff or Failure Hazard Rate}_{\text{vendor}}}{\text{Relevant Liquidity for Hazard Rate}_{\text{vendor}}} \tag{7.19}
\]

The relevant liquidity for affecting hazard rate is when perceived liquidity is lower than 1. When it is greater than 1, hazard rate stays at the normal rate. Perceived liquidity is the ratio of working capital to target cash required to support the firm's expenditures. Note that I assume there is no significant delay or bias in the employee's perception of the firm's cash position (i.e., transparency). This assumption could be relaxed by including delays or biases that would, for example, prevent employees from discovering that a firm was in financial difficulty, as at Enron and WorldCom. Target cash on hand is determined
by desired cash coverage as the firm seeks to maintain cash sufficient to provide certain coverage of its required expenditures.

Relevant Liquidity for Hazard Rate[vendor]

\[ \text{Relevant Liquidity for Hazard Rate[vendor]} = \min(1, \text{Perceived Liquidity[vendor]}) \]  

(7.20)

Perceived Liquidity[vendor]

\[ \text{Perceived Liquidity[vendor]} = \frac{\text{Working Capital[vendor]}}{\text{Target Cash on Hand[vendor]}} \]  

(7.21)

Target Cash on Hand[vendor]

\[ \text{Target Cash on Hand[vendor]} = \text{Desired Cash Coverage[vendor]} \times \text{Required Payments[vendor]} \]  

(7.22)

7.5.3 Expected Present Value of Profit Sharing

Expected present value of profit sharing equals expected profit sharing discounted at the discount rate for total compensation. The expected profit sharing per employee is a smooth function of the actual profit sharing per employee. Profit sharing amount equals net income multiplied by profit sharing as percentage of net income, provided that net income is positive.

Expected Present Value of Profit Sharing[vendor, department]

\[ \text{Expected Present Value of Profit Sharing[vendor, department]} = \frac{\text{Expected Profit Sharing per Employee[vendor,department]}}{\text{Discount Rate for Total Compensation[vendor]}} \]  

(7.23)

Expected Profit Sharing per Employee[vendor,department]

\[ \text{Expected Profit Sharing per Employee[vendor,department]} = \text{SMOOTH(Profit Sharing per Employee[vendor,department], Time to Adjust Expected Profit Sharing)} \]  

(7.24)

Profit Sharing per Employee[vendor,department]

\[ \text{Profit Sharing per Employee[vendor,department]} = \frac{\text{Profit Sharing Amount[vendor]}}{\text{Total Employees[vendor]}} \]  

(7.25)
\[
\text{MAX}(0, \text{Net Income Before Profit Sharing[vendor]} \times \text{Profit Sharing as Percentage of Net Income[vendor]}/100) \quad (7.26)
\]

### 7.5.4 Expected Present Value of Stock Grants

Expected present value of stock grants equals the average stock granted per employee times the expected value of non-vested stock grants discounted at the discount rate for total compensation.

\[
\text{Expected Present Value of Stock Grants[vendor,department]} = \text{Stock Granted per Existing Employee[vendor,department]} \times \text{Expected Value of Non Vested Stock Grants[vendor,department]} / \text{Discount Rate for Total Compensation[vendor]} \quad (7.27)
\]

Expected value of non-vested stock grants equals the expected stock price discounted at a specified rate over the vesting period – the higher the discount rate or longer the vesting period, the lower the expected value of non-vested stock grants held.

\[
\text{Expected Value of Non Vested Stock Grants[vendor,department]} = \text{Expected Stock Price[vendor]} \times \exp(-\text{Discount Rate for Total Compensation[vendor]} \times \text{Stock Grant Vesting Period[vendor,department]}) \quad (7.28)
\]

### 7.5.5 Expected Present Value of Stock Options

Expected present value of stock options is the average employee’s non-vested option holdings discounted at a specified rate over the vesting period – the higher the discount rate or longer the vesting period, the lower the present value of the options held.

\[
\text{Expected Present Value of Stock Options[vendor,department]} = \text{Expected Value of Non Vested Stock Options[vendor,department]} \times \exp(-\text{Discount Rate for Total Compensation[vendor]} \times \text{Vesting Period[vendor,department]}) \quad (7.29)
\]
Expected Value of Non Vested Stock Options[vendor,department]
= Expected per Share Option Value[vendor,department] * Non Vested Options per employee[vendor,department] (7.30)

The per-share value of the non-vested options of each employee is a function of the difference between the expected share price and the average strike price of their non-vested options. The function represents the subjective valuation, in the minds of employees, of the option value (roughly the Black-Scholes value but potentially biased by employee optimism about future share value or volatility). When stock options are in the money, employees value them close to the current value. As they begin to go underwater, the subjective value gradually declines to zero (Figure 7.7).

Expected per Share Option Value[vendor,department]
= Average Strike Price of Non Vested Options[vendor,department] * Option Value as Fraction of Strike Price[vendor,department] (7.31)

Option Value as Fraction of Strike Price[vendor,department] = Function for Expected Option Value(Fractional Option Value[vendor,department]) (7.32)

Figure 7.7: Function for Expected Option Value
Fractional Option Value[vendor,department] = (Expected Stock Price[vendor]-Average Strike Price of Non Vested Options [vendor,department])/Average Strike Price of Non Vested Options[vendor,department] \hspace{1cm} (7.33)

Expected Stock Price[vendor] = SMOOTH(Stock Price[vendor], Time for Adjust Expectations for Stock Price) \hspace{1cm} (7.34)

### 7.6 Stock Grants

See Figure 7.8 for the diagram of the stock grant sector. Stock grants can be awarded to each new hire and existing employee. The total number of stock grants equals the sum of stock granted to new and existing employees.

\[
\text{Stock Grants Awarded}[\text{vendor,department}] = \text{Stock Grants Awarded to New Hires}[\text{vendor,department}] + \text{Stock Grants Awarded to Existing Employees}[\text{vendor,department}] \hspace{1cm} (7.35)
\]

Each new hire receives the number of stock grants worth a certain target value set by managers. The current share price is used to determine the number of shares awarded.

\[
\text{Stock Grants Awarded to New Hires}[\text{vendor,department}] = \text{Stock Granted per Hire}[\text{vendor,department}] \times \text{Rookie Hire Rate}[\text{vendor,department}] \hspace{1cm} (7.36)
\]

\[
\text{Stock Granted per Hire}[\text{vendor,department}] = \frac{\text{Target Value of Stock Grants for New Hires}[\text{vendor,department}]}{\text{Stock Price}[\text{vendor}]} \hspace{1cm} (7.37)
\]

Each existing employee receives a certain number of stock grants worth a certain value set by the manager. The value of stock granted to each employee annually is modeled as a percentage of industry average compensation. For example, suppose the industry average compensation is $100,000 per person per year. If one would like to award stock grants worth 10% of the industry compensation ($10,000 per person per year), and the
<table>
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<td>Stock Price</td>
<td>Employee Stock Price</td>
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</table>

**Figure 7.6: Stock Grants Sector**
internal stock price is $10 per share at the time stock is granted, each employee would receive 1000 shares per year. Shares granted per existing employees equals the total value of stock granted per employees ($/year/person) divided by the stock price ($/share), capped at minimum stock price = 1 to prevent extremely large shares being granted when the stock price is infinitely small.

Stock Grants Awarded to Existing Employees[vendor,department]  
= Stock Granted per Existing Employee[vendor,department] * Total Employees per Department[vendor,department]  

(7.38)

Stock Granted per Existing Employee[vendor,department] = Value of Stock Granted per Existing Employee[vendor,department]/MAX(1,Stock Price[vendor])  

(7.39)

Value of Stock Granted per Existing Employee[vendor,department]  
= Reference Total Compensation[department] * Stock Granted for Existing Employees as Percentage of Industry Compensation[vendor]/100  

(7.40)

Stock grants are restricted stock that transits from a non-vested stock grant to vested employee shares to former employee shares when employees leave the company. The total number of non-vested shares held by employees increases as stocks are awarded, decreases as stocks vest or expire on the attrition of employees.

Non Vested Stock Grants[vendor,department]  
= INTEG (Stock Grants Awarded[vendor,department] - Non Vested Stock Grants Expiring[vendor,department] - Stock Grants Vested[vendor,department], Initial Non Vested Stock Grants[vendor,department])  

(7.41)

Initial Non Vested Stock Grants[vendor,department] = Total Employees per Department[vendor,department] * Stock Granted per Hire[vendor,department]  

(7.42)

Non-vested shares expire when the employees holding them leave the firm. Each employee leaving is assumed to reduce the stock of non-vested shares by the average
number of non-vested shares per employee. Stock grants are assumed to be vested over a vesting period of 3 years.

Non Vested Stock Grants Expiring[vendor,department] = Non Vested Stock Grants per Employee[vendor,department] * Total Quit Rate[vendor,department]  

(7.43)

Stock Grants Vested[vendor,department] = Non Vested Stock Grants[vendor,department]/Stock Grant Vesting Period[vendor,department]  

(7.44)

The number of vested stock grants increases as non-vested stock grants vest. When employees quit, they take their vested stock with them. These shares enter into the accumulated stock of Former Employee Shares. Former employees can decide how many shares they would like to sell to the existing employees at the current stock price. This assumes there is an internal stock valuation where employees can buy and sell shares with each other. This is similar to the mechanism set up by the employee-owned company Scientific Application International Corporation (Beyster and Economy 2007).

Employee Shares[vendor,department]  

= INTEG (Stock Grants Vested[vendor,department] - Employee Shares Exiting[vendor,department] + Repurchased Employee Shares[vendor, department], 0)  

(7.45)

Employee Shares Exiting[vendor,department]  

= Total Quit Rate[vendor,department] * Shares per Employee[vendor,department]  

(7.46)

Repurchased Employee Shares[vendor,department]  

= Employee Shares Exiting[vendor,department] * Fraction of Repurchased Employee Shares Upon Termination[vendor]  

(7.47)

Former Employee Shares[vendor,department]  

= INTEG (Employee Shares Exiting[vendor,department] - Repurchased Employee Shares[vendor, department],0)  

(7.48)
Cost of Repurchased Employee Shares per Employee[vendor,department] \quad (7.49) \\
= \text{Stock Price[vendor]} \times \text{Repurchased Employee Shares per Employee[vendor,department]}

Repurchased Employee Shares per Employee[vendor,department] \quad (7.50) \\
= \frac{\text{Repurchased Employee Shares[vendor,department]} / \text{Total Employees per Department[vendor,department]}}{}

### 7.7 Stock Options

Figure 7.9 shows the stock options sector based on Oliva, Sterman and Giese (2003). Similar to the stock grants structure, options can be awarded to new hires and existing employees with a vesting period of 3 years. Non-vested options expire when the employees holding them leave the firm. Each employee leaving reduces the stock of non-vested options by the average number of non-vested options per employee. Vested options either get exercised when it is in the money (stock price greater than average strike price of vested options), or expired after an average life of 5 years. There is a co-flow structure tracks the total basis cost of the non-vested and vested options. The average basis cost of the vested options is the sum of all strike prices divided by the number of vested options outstanding.

Annual Stock Options per Employee as a Basis Point of Total Shares (ASO) captures the policy of compensating employees by offering them annual stock options. The number of stock options is modeled as a basis point of the total shares outstanding. Thus, a policy of 5 basis points of ASO means granting each employee the number of options worth of 0.0005 of total shares. For instance, if the firm starts with one million shares, each employee will receive 500 options per year.
Figure 7.9: Stock Options Sector

- Average Strike Price of Non Vested Options
- Non Vested Employee Options
- Vested Employee Options
- Time to Reprice Options
- Indicated Repricing of Non Vested Options
- Repricing of Non Vested Options
- Stock Price
- Total Basis of New Options
- Strike Price of New Options
- Option Price Relative to Share Price
- Rookie Hire Rate
- Target Value of Options for New Hires
- Options Granted per Hire
- Options Awarded to New Hires
- Options Awarded to Existing Employees
- Options Granted per Existing Employee per Year
- Non Vested Employee Options
- Options Awarded
- Options Expiring
- Options Vesting
- Annual Stock Options per Employee as a Basis Point of Total Shares
- Total Employees per Department
- Shares Outstanding
- Average Strike Price of Vested Options
- Time to Reprice Options
- Stock Price
- Total Basis of Options Expiring
- Total Strike Price of Options Expiring
- Average Strike Price of Non Vested Options
- Stock Price
- Options Exercised
- Vested Options Reaching Expiration Date
- Average Life of Vested Options
- Fraction of Options Exercised
- Stock Price
- Average Strike Price of Vested Options
- Time to Reprice Options
- Stock Price
- Total Basis of Options Exercised
- Total Basis of Options
- Total Basis of Non Vested Options
- Total Basis of Vested Options
- Stock Price
- Options Awarded
- Options Expiring
- Options Vesting
- Options Exercised
- Company in Operation Switch
- Options Granted per Employee per Year
- Options per Employee
- Average Life of Vested Options
- Stock Price
- Average Strike Price of Vested Options
- Time to Reprice Options
- Stock Price
- Total Basis of Options Exercised
- Total Basis of Options
- Total Basis of Non Vested Options
7.8 Financial Market

Figure 7.10 shows the financial market sector, drawn from Oliva, Sterman and Giese (2003). Stock price is the firm's total market value divided by the number of shares outstanding. The market value of the firm is assumed to be the greater of the expected present value of future profits or the breakup value of the firm. Expected profits are discounted prior to the IPO because the stock is less liquid as an investment. The minimum value of the firm is its breakup or liquidation value, given by its cash less its liabilities.

\[
\text{Stock Price} = \frac{\text{Market Capitalization}}{\text{Shares Outstanding}} \quad (7.51)
\]

\[
\text{Market Capitalization} = \max (\text{Breakup Value}, \text{Expected Present Value of Profit} \times \text{Pre IPO Discount}) \quad (7.52)
\]

\[
\text{Breakup Value} = \max (0, \text{Working Capital} - \text{Total Liabilities}) \quad (7.53)
\]

\[
\text{Pre IPO Discount} = \begin{cases} 0.75, & \text{if } \text{Time} \leq \text{IPO Date} \\ 1, & \text{otherwise} \end{cases} \quad (7.54)
\]

The expected present value of the firm's profit is the net present value of expected net income, adjusted for future expected growth. The growth-adjusted discount factor is based on the discount rate for earnings, adjusted to reflect investors' expectations for future growth in earnings, and constrained to be nonnegative (in the case where expected net income is negative, such as when the firm consistently loses money). The discount rate used to value the expected earnings of the firm is a nonlinear function of the discount rate and the expected rate of growth in future earnings. The nonlinear function keeps the effective discount rate nonnegative when the denominator is less than zero. The minimum
Time to Adjust Sales Growth Expectations

Recent Sales Revenue

Effective Sales Revenue for Growth Rate

Base for Growth Rate Calculation

Financial Results Reporting Time

Historic Sales Revenue

Indicated Growth in Revenue

Discount Rate

Sensitivity of Valuation to Rapid Growth

Growth Adjusted Discount Factor

Initial Expected Revenue Growth

Expected Growth in Revenue

Expected Present Value of Profit

Net Income

Expected Long Run Return on Sales

Expected Net Income

Return on Sales

Market share

Total Market

Recent Net Income

Indicated Industry Return on Sales

Initial Expected Return on Sales

Expected Steady State Net Income

Expected Net Income

Investment Rate Calculation

Valuation Weight Adjustment Time

Weight on Actual Net Income After Startup Honeymoon Period

Honeymoon Period

Startup Date

Time to Adjust Expected Long Run Return on Sales

Weight on Actual Net Income for Valuation

Valuation Weight

Operation Switch

Company in

Expected Steady State Return on Sales

Return on Sales

Indicated Industry Return on Sales

Initial Expected Return on Sales

Expected Net Income

Time to Adjust Honeymoon Expected Long Run Return on Sales

Honeymoon Weight on Actual Net Income for Valuation

Time to Adjust Sales Growth Expectations

Discount Rate

Sensitivity of Valuation to Rapid Growth

Growth Adjusted Discount Factor

Initial Expected Revenue Growth

Expected Growth in Revenue

Expected Present Value of Profit

Net Income

Expected Long Run Return on Sales

Expected Net Income

Return on Sales

Market share

Total Market

Recent Net Income

Indicated Industry Return on Sales

Initial Expected Return on Sales

Expected Steady State Net Income

Expected Net Income

Investment Rate Calculation

Valuation Weight Adjustment Time

Weight on Actual Net Income After Startup Honeymoon Period

Honeymoon Period

Startup Date

Time to Adjust Expected Long Run Return on Sales

Weight on Actual Net Income for Valuation

Valuation Weight

Operation Switch

Company in
value of the function is the inverse of the maximum P/E ratio the capital markets are willing to pay.

Expected Present Value of Profit\[vendor\]  
(7.55)  
= \text{MAX} (0, \text{Expected Net Income}[\text{vendor}])/\text{Growth Adjusted Discount Factor}[\text{vendor}]

Growth Adjusted Discount Factor[\text{vendor}]
(7.56)
= IF THEN ELSE (Discount Rate - Expected Growth in Revenue[\text{vendor}] > 0.04, Discount Rate - Expected Growth in Revenue[\text{vendor}], 0.04 * exp (Sensitivity of Valuation to Rapid Growth * (Discount Rate - Expected Growth in Revenue[\text{vendor}] - 0.04)))

The expected profit of the firm used to value the firm is a weighted average of current profit and the expected steady-state profit the firm is expected to achieve. The weight on actual net income is low during the startup honeymoon period, when investors are willing to tolerate losses while the firm invests in growth (through high expenditures and low prices). After the startup honeymoon, however, investors revert to traditional valuation measures based on the actual profitability of the firm. The financial results of the firm are reported with a delay.

Expected Net Income[\text{vendor}]
(7.57)
= Weight on Actual Net Income for Valuation[\text{vendor}] * Recent Net Income[\text{vendor}] + (1 - Weight on Actual Net Income for Valuation[\text{vendor}]) * Expected Steady State Net Income[\text{vendor}]

Recent Net Income[\text{vendor}]
(7.58)
= \text{SMOOTH} (\text{Net Income}[\text{vendor}], \text{Financial Results Reporting Time})

Once the startup honeymoon period ends, the weight investors give to actual net income in their valuation of the firm is assumed to adjust with a delay.

Weight on Actual Net Income for Valuation[\text{vendor}]
(7.59)
= \text{SMOOTH3i} (\text{Weight on Actual Net Income After Startup Honeymoon Period}
Investors expect the profits of the firm, over the long haul, to be a certain fraction of recent sales revenue.

Expected Steady State Net Income = Expected Long Run Return on Sales * Recent Sales Revenue for Growth Rate

Recent sales revenue for growth rate is smoothed over a short period to filter out noise. It is initialized in steady state at the initial expected growth rate (see Sterman 2000, Chapter 16).

Recent Sales Revenue for Growth Rate = SMOOTHI (Effective Sales Revenue for Expected Growth, Financial Results Reporting Time, Effective Sales Revenue for Expected Growth/(1 + Initial Expected Revenue Growth * Financial Results Reporting Time))

Effective sales revenue for expected growth is the greater of actual sales or a base that represents a minimum revenue level, so that expected growth rates remain reasonable when sales are very small (the growth rate on the first sale is infinite, but expectations will not rise to infinity).

Effective Sales Revenue for Expected Growth = MAX (Base for Growth Rate Calculation, Revenue)

Base for Growth Rate Calculation = 1e+006

Investors' expected long-run return on sales is adjusted gradually from the initial level to the indicated level of industry return on sales. The indicated level is set to the initial expectation until a sufficient time has passed for investors to compile data on and assess industry experience.
Expected Long Run Return on Sales[vendor] \[ (7.64) \]

\[ = \text{SMOOTH3i (Indicated Industry Return on Sales[vendor], Time to Adjust Expected Long Run Return on Sales, Initial Expected Return on Sales)} \]

Indicated Industry Return on Sales[vendor] \[ (7.65) \]

\[ = \text{IF THEN ELSE (Time > Honeymoon Period End Date[vendor], Industry Average Return on Sales, Initial Expected Return on Sales)} \]

Industry average return on sales is the return on sales of each firm weighted by its market share.

Industry Average Return on Sales \[ (7.66) \]

\[ = \text{SUM (Market share[vendor!] * Return on Sales[vendor!]})} \]

Honeymoon Period End Date[vendor] \[ (7.67) \]

\[ = \text{Startup Date[vendor] + Honeymoon Period} \]

Honeymoon Period = 4 \[ (7.68) \]

### 7.9 Accounting

Accounting sector includes income statement, cash flow and balance sheet of the firm. It is based on Oliva, Sterman and Giese (2003) and the standard accounting procedure.

#### 7.9.1 Income Statement

Figure 7.11 shows the income statement. Net income equals revenue subtracting profit-sharing amount, required tax payment, extraordinary charges, operating expenses (which
are composed of salary, general and administrative (G&A) expenses and marketing expenses), depreciation and cost of goods sold.

Net Income[vendor] (7.69)
= Net Income Before Profit Sharing[vendor] - Profit Sharing Amount[vendor]

Net Income Before Profit Sharing[vendor] (7.70)
= Net Income Before Tax[vendor] - Required Tax Payment[vendor]

Net Income Before Tax[vendor] (7.71)
= Operating Income[vendor] - Extraordinary Charges[vendor]

Operating Income[vendor] (7.72)
= Gross Profit[vendor] - Operating Expenses[vendor] - Depreciation[vendor]


Billing for COGS[vendor] (7.75)
= Product COGS[vendor] + Maintenance COGS[vendor]

Total revenue is the sum of revenue from new sales and subsequent service fee.

Revenue[vendor] (7.76)
= Revenue from New Sales[vendor] + Revenue from Service[vendor]

Revenue from New Sales[vendor] = Price[vendor] * Purchase Rate[vendor] (7.77)

Revenue from Service[vendor] (7.78)
= Annual Service Fee per Unit[vendor] * Installed Base[vendor]
Figure 7.11: Income Statement Sector

- Purchase Rate
  - <Price>
  - Revenue from New Sales
- Annual Service Fee per Unit
- <Installed Base>
  - Revenue from Service
  - Revenue
- <Maintenance COGS>
- <Product COGS>
  - Billing for COGS
  - Gross Profit
- <General and Administrative Expense>
- <Salary Expense>
  - Operating Expenses
  - Operating Income
  - Depreciation
  - Extraordinary Charges
  - Net Income Before Tax
- Required Tax Payment
  - Net Income Before Profit Sharing
- <Profit Sharing Amount>
  - Net Income
7.9.2 Cash Flow

Figure 7.12 shows the sector of cash flow. Cash flow equals to the sum of cash flows from operations, investing and financing.

\[
\text{Cash Flow}\[\text{vendor}\] = \text{Cash Flow from Operations}\[\text{vendor}\] + \text{Cash Flow from Investing}\[\text{vendor}\] + \text{Cash Flow from Financing}\[\text{vendor}\]
\]

(7.79)

Cash Flow from Operations\[\text{vendor}\] (7.80)
\[
= \text{Receipt of Accounts Receivable}\[\text{vendor}\] - \text{Payments for Operating Expense}\[\text{vendor}\]
\]

Cash Flow from Investing\[\text{vendor}\] (7.81)
\[
= \text{Proceeds from Sale of Assets}\[\text{vendor}\] - \text{Proceeds from Acquisition of Assets}
\]

Cash Flow from Financing\[\text{vendor}\] (7.82)
\[
= \text{Proceeds from Sale of Equity}\[\text{vendor}\] - \text{Proceeds from Acquisition of Equity}\[\text{vendor}\]
\]

The rate at which money is raised by sale of equity depends on the value of shares sold in the IPO, to VCs, plus the value of any shares sold in secondary offerings, and the funds received from the proceeds from options exercised by employees (the strike price multiplied by the number of options exercised by employees).

Proceeds from Sale of Equity\[\text{vendor}\] (7.83)
\[
= \text{Proceeds from IPO}\[\text{vendor}\] + \text{Proceeds from VC financing}\[\text{vendor}\] + \text{Proceeds from Shares Sold to Public}\[\text{vendor}\] + \text{Proceeds from Employee Options }[\text{vendor}]
\]

Proceeds from VC financing\[\text{vendor}\] = Funds Raised From VCs\[\text{vendor}\] (7.84)

Proceeds from IPO\[\text{vendor}\] = IPO Shares\[\text{vendor}\] * Stock Price\[\text{vendor}\] (7.85)

Proceeds from Shares Sold to Public\[\text{vendor}\] (7.86)
\[
= \text{New Shares Issued to Public}\[\text{vendor}\] * \text{Stock Price}\[\text{vendor}\]
\]
Proceeds from Employee Options[vendor]  
\[ (7.87) \]
\[ = \text{SUM (Total Basis of Options Exercised[vendor,department!])} \]

The financing the firm requires is (nonnegative part of) the amount needed to adjust the cash balance to the target level less the firm's cash flow before financing. Note that I do not model the possibility of share buybacks. Financing required is constrained to be nonnegative. Expected cash flow before financing is the sum of revenue and any revenue from assets sold less required expenditures.

Financing Required[vendor] = MAX \( 0, \text{Adjustment to Financing for Cash[vendor]} - \text{Cash Flow Before Financing [vendor]} \)  
\[ (7.88) \]

Cash Flow Before Financing[vendor]  
\[ (7.89) \]
\[ = \text{Receipt of Accounts Receivable[vendor]} - \text{Required Payments[vendor]} + \text{Cash Flow from Investing[vendor]} \]

The firm is assumed to adjust its cash balance to a target level that is sufficient to provide certain coverage of its required expenditures.

Adjustment to Financing for Cash[vendor]  
\[ (7.90) \]
\[ = \text{MAX}(0, (\text{Target Cash on Hand[vendor]} - \text{Working Capital[vendor]}) / \text{Time to Adjust Cash}) \]

Target Cash on Hand[vendor]  
\[ (7.91) \]
\[ = \text{Desired Cash Coverage[vendor]} \times \text{Required Payments[vendor]} \]
7.9.3 Balance Sheet

Figure 7.13 shows the balance sheet sector. It keeps track of assets (working capital and account receivable) and liabilities (account payable, pay in capital and cumulated retained earnings) following the standard accounting procedure.
7.10 Prospect Chain

The market sector of the model follows Miller (2007) closely, with changes to the formulations for how sales flow through from one chain to another. The prospect chain is based on the Bass diffusion model (Bass, 1969). It has been extended to more closely approximate the sales cycle of the clean energy technology companies based on interviews and case studies done by Miller (2007). See Figure 7.14 for a depiction of the stocks and flows of the prospect chain.

The stocks of prospects along the chain are based on the sales experiences of the companies interviewed by Miller; the research indicated points at which prospects get “stuck” and where prospects are lost. The units of the stocks, which are “prospects,” represent commercial enterprises that are capable of purchasing and adopting the product of the clean technology startup being modeled. The driver for prospects to move along the prospect chain is the sales effort of the startup, which is made more or less productive by the startup’s product attractiveness in comparison with that of the competitors. The model is capable of representing multiple startup competitors. However, for simplicity, the analysis done in this thesis assumes that there is only one startup firm competing against the incumbent, who offers the conventional way of operating energy use (such as the traditional HVAC systems). The startup’s product attractiveness is driven by customer payback period, customer support, marketing effort and word of mouth.

The prospect chain includes the following stocks:

- **Potential Customers:** This is the group of firms that can possibly adopt the clean energy product at some point in the future. This captures the concept of an addressable market size, which is driven by the attractiveness of the startup’s product offering.

- **Potential Prospects:** These are firms that are capable of adopting the current version of the product. The startup has identified these firms and chosen to apply sales effort to persuade them to learn more about the product.

- **Prospects:** These are firms that are capable of adopting the product and have been made aware of the product by the startup, and have not ruled out adopting it. The
startup has decided to apply sales effort to persuade these firms to trial the product or otherwise to learn enough about it to be able to make the decision to adopt it or not.

- **Hot Prospects**: These are firms that have expressed interest in adopting the product and are either actively trialing it or evaluating it in some other fashion.

- **Adopters**: These are firms that have purchased and are actively using the product. Adopters can be poached by other firms after 10 years of adoption.

- **Lost Prospects**: These are firms that were prospects (anywhere from potential prospects to hot prospects) that lost interest in considering the product or made the decision not to adopt. They could become interested and reenter the potential prospects stock after one year.

### 7.11 Product Development

The product development sector of the model is based on the inventory management sector described in section 18.1 of Sterman (2000) and on Miller (2007). The firm develops its product features through engineering effort. See Figure 7.15 for a diagram of the product development sector. Full model documentation is listed in the appendix.
7.12 Alpha Inc.’s Initial Conditions

To initialize the model, I did a field research at a startup company, Alpha Inc. (pseudonym), that develops integrated energy efficiency systems for commercial and industrial buildings. Its innovative technology aims to lower building operating costs for electricity, heating and cooling by over 75% from traditional HVAC systems.

Table 7.1 is a list of parameter values used in the model based on Alpha Inc’s current condition. Given the inherent limitation of an early-stage startup, where there are no later-stage time-series data, the company data was used to parameterize the initial conditions of the model. I also interviewed the executives concerning their decision rules regarding pricing, financing, human resource and compensation policies and their projections of the business performance.

Table 7.1: Selected Parameter Values

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>INITIAL VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td></td>
</tr>
<tr>
<td>Potential Market Size (people)</td>
<td>100,000</td>
</tr>
<tr>
<td>Sales Cycle Time (year)</td>
<td>1</td>
</tr>
<tr>
<td>Reference Sales Effort Productivity (prospect/person/hour)</td>
<td>0.1</td>
</tr>
<tr>
<td>Product Development</td>
<td></td>
</tr>
<tr>
<td>Initial Feature Relative to Incumbent (index)</td>
<td>4</td>
</tr>
<tr>
<td>Average Product Development Time (year)</td>
<td>1</td>
</tr>
<tr>
<td>Engineer Hours Required per Feature (person*hours/feature)</td>
<td>100</td>
</tr>
<tr>
<td>Product Useful Life (year)</td>
<td>20</td>
</tr>
<tr>
<td>Human Resources</td>
<td></td>
</tr>
<tr>
<td>Initial Sales Force (people)</td>
<td>0</td>
</tr>
<tr>
<td>Initial Engineers (people)</td>
<td>5</td>
</tr>
<tr>
<td>Average Time to Fill Employee Vacancies (year)</td>
<td>0.167</td>
</tr>
<tr>
<td>Assimilation Time (year)</td>
<td>2</td>
</tr>
<tr>
<td>Industry Quit Fraction (1/year)</td>
<td>0.1</td>
</tr>
<tr>
<td>Reference Total Compensation ($/person/year)</td>
<td>100,000</td>
</tr>
<tr>
<td>Rookie Compensation Relative to Experienced Employee (dimensionless)</td>
<td>0.667</td>
</tr>
<tr>
<td>Workweek per Year (week/year)</td>
<td>50</td>
</tr>
<tr>
<td>Category</td>
<td>Value</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>Normal Workweek (hour/week)</td>
<td>40</td>
</tr>
<tr>
<td>Burnout Time (year)</td>
<td>0.25</td>
</tr>
<tr>
<td>Customer Support Needed per Customer</td>
<td>45</td>
</tr>
<tr>
<td>Price</td>
<td></td>
</tr>
<tr>
<td>Initial Incumbent Price ($/unit)</td>
<td>16,000</td>
</tr>
<tr>
<td>Initial Price ($/unit)</td>
<td>80,000</td>
</tr>
<tr>
<td>Initial Markup Ratio (dimensionless)</td>
<td>0.3</td>
</tr>
<tr>
<td>Annual Service Fee Relative to Product Price</td>
<td>0.05</td>
</tr>
<tr>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Initial Operating and Maintenance Costs ($/unit/year)</td>
<td>2,400</td>
</tr>
<tr>
<td>Initial Energy Use (kWh/Year/Unit)</td>
<td>180,000</td>
</tr>
<tr>
<td>Initial Energy Price ($/kWh) (2/3 * 0.05/kWh (gas) + 1/3 * 0.15/kWh (electricity))</td>
<td>0.083</td>
</tr>
<tr>
<td>Fractional Percentage Growth Rate of Energy Price (1/year)</td>
<td>5</td>
</tr>
<tr>
<td>CO2 Emission per kWh (tons/kWh)</td>
<td>0.000606</td>
</tr>
<tr>
<td>Discount Rate for Energy Costs (1/year)</td>
<td>0.04</td>
</tr>
<tr>
<td>Finance</td>
<td></td>
</tr>
<tr>
<td>Initial Investment ($)</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Fixed G&amp;A Expense ($)</td>
<td>200,000</td>
</tr>
<tr>
<td>Unit G&amp;A Expense ($/unit)</td>
<td>1,000</td>
</tr>
<tr>
<td>Desired Cash Coverage (year)</td>
<td>0.167</td>
</tr>
<tr>
<td>Venture Capital</td>
<td></td>
</tr>
<tr>
<td>Time for VC Application (year)</td>
<td>1</td>
</tr>
<tr>
<td>Required Factor of Return for VC (dimensionless)</td>
<td>10</td>
</tr>
<tr>
<td>VC Financing Effort per Dollar (Person*Hours/Year/$)</td>
<td>0.001</td>
</tr>
<tr>
<td>Founders Shares Outstanding (shares)</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Stock Options and Grants</td>
<td></td>
</tr>
<tr>
<td>Stock Options Vesting Period (year)</td>
<td>3</td>
</tr>
<tr>
<td>Desired Options Pool Fraction (dimensionless)</td>
<td>0.15</td>
</tr>
<tr>
<td>Average Life of Vested Options (year)</td>
<td>5</td>
</tr>
<tr>
<td>Stock Grants Vesting Period (year)</td>
<td>3</td>
</tr>
</tbody>
</table>
8. DATA AND REGRESSION ESTIMATION

This chapter presents the dataset that is used to estimate the non-linear functional forms of various relationships in the model.

8.1 Data

To build a formal simulation model of the causal structure shown in Figure 6.4, it is important to estimate the functional forms of each linkage, such as the effect of financial compensation on job satisfaction. One way to quantitatively estimate the relationship is to gather a random sample of employees with enough variation in the variables listed in Figure 6.4, and run a regression to estimate the relationship, controlling for other variables. For this purpose, I run regressions using the National Bureau of Economic Research (NBER)'s Shared Capitalism dataset (Kruse, Freeman and Blasi 2010).²

8.1.1 NBER Shared Capitalism Dataset

The NBER Shared Capitalism dataset is a company survey that administered 80 to 100 questions to 41,206 employees in fourteen firms at 323 work sites who had some shared capitalism modes of compensation. It is the single largest dataset conducted on workers in shared capitalism firms. All of the firms interviewed exercise some sort of broad-based employee ownership plan. The plan types vary: eight have standard Employee Stock Ownership Plans (ESOPs), one has a 401(k) ESOP, four have Employee Stock Purchase Plans (ESPPs), and three have 401(k)s with company stock. Eleven of the firms have broad-based profit-sharing plans, while five have broad-based stock option plans. The 80 to 100 survey questions cover most of the variables found in a typical HPWS with shared capitalism modes of compensation, making this NBER dataset the best available source I know for estimating this study's Employee Ownership model. The NBER's over 40,000 data entries allow me to segment the data and estimate the non-linear relationships in the model.

² I would like to thank Professors Joseph Blasi and Douglas Kruse of Rutgers University for their generosity in sharing their valuable data and conducting regression analyses with me.
8.1.2 Limitations of the Data

There are, however, two potential drawbacks to the data. First, the NBER firm survey is a self-selected nonrandom sample of US establishments. To the extent that the survey questions relate to issues facing all firms and reflecting human nature, there is good reason to expect any findings to generalize to a broader population. The empirical study of management and firm behavior and much of psychology is replete with in-depth and useful analysis of nonrandom samples, often of just a single firm or person (Kruse, Freeman and Blasi 2010). The NBER data set with over 40,000 respondents is a significant improvement over the existing literature for estimating the relationships of various employee ownership and human resource policies. Future data collection efforts could focus on time series within one firm or panel data across firms in a randomized sample.

Second, this is self-reported data as opposed to objective financial data. For example, the question for the variable “Profit sharing as % of pay” is “what was the approximate total dollar value of the payment(s) you received [in the most recent year of bonuses] divided by basepay + overtime, otherwise 0”. While the employees are asked to report objective data, there may be some bias if certain types of employees are more likely to underreport, overreport, or not report the values (e.g., if those with negative attitudes are more likely to underreport profit sharing). Obtaining administrative data on these variables would be theoretically preferable, but attempting to match such data to individual surveys would violate the anonymity of the survey and lower response rates. The self-reported financial data provide the best available data to date for estimating shared capitalism effects.
8.2 Overview of Regression Estimates

I used the NBER Shared Capitalism dataset to estimate the five table functions in Figure 8.1. Each thick line with a number indicates a table function estimated from the NBER dataset. This section explains each function in detail.

Figure 8.1: Estimated Table Functions Using NBER Shared Capitalism Dataset

[Diagram of employee + net worth, stock price, red: human resource policies, green: job satisfaction drivers, blue: employee behavior indicators]
8.3 Effect of Financial Compensation on Job Satisfaction

To estimate the effects of financial compensation, employee ownership stake and profit sharing on job satisfaction (#1, 2 and 3 links in Figure 8.1), the regression equation 8.1 below is performed. Job satisfaction is regressed on compensation greater and less than average, employee ownership stake as percent of pay, profit sharing as percent of pay, number of stock options in last year, training hours, job security, supervision, and employee participation. One potential missing variable is the length of work time for capturing the burnout effect, indicating how people are less happy when they work too long without rest. Another missing variable is the intrinsic motivation people derive from the meaning of their work. Future research would benefit from adding these topics to the survey.

\[ \text{Job Satisfaction} = a + b_1 \times \text{Compensation Greater Than Average} + b_2 \times (\text{Compensation Greater Than Average})^2 + b_3 \times \text{Compensation Less Than Average} + b_4 \times (\text{Compensation Less Than Average})^2 + b_5 \times \text{Employee Ownership Dummy} + b_6 \times \text{Employee Ownership Stake Over Pay} + b_7 \times (\text{Employee Ownership Stake Over Pay})^2 + b_8 \times \text{Profit Sharing Dummy} + b_9 \times \text{Profit Sharing Over Pay} + b_{10} \times (\text{Profit Sharing Over Pay})^2 + b_{11} \times \text{Stock Options Dummy} + b_{12} \times \text{Stock Options} + b_{13} \times (\text{Stock Options})^2 + b_{14} \times \text{Training Dummy} + b_{15} \times \text{Training Hours} + b_{16} \times (\text{Training Hours})^2 + b_{17} \times \text{Job Security} + b_{18} \times \text{Supervision} + b_{19} \times \text{Participation} + \text{Error} \]  

(8.1)

The regression uses linear and squared terms of total compensation, employee ownership stake over pay, profit sharing over pay, stock options, training hours to model non-linearities, with separate linear and squared terms for total compensation less than industry average and greater than industry average. Table 8.1 shows the regression results for job satisfaction. All variables have the expected signs and the conventional significance levels except the number of stock options, which is statistically insignificant.
Table 8.1: Results of Regression Analysis for Job Satisfaction

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Std. Err.</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.4048***</td>
<td>.1167</td>
<td>2.1759</td>
</tr>
<tr>
<td>Compensation Greater Than Average</td>
<td>.0063***</td>
<td>.0006</td>
<td>.0051</td>
</tr>
<tr>
<td>Compensation Greater Than Average Squared</td>
<td>-9.6e-06***</td>
<td>.00002</td>
<td>-9.0e-06</td>
</tr>
<tr>
<td>Compensation Less Than Average</td>
<td>-.0158***</td>
<td>.0008</td>
<td>-.0175</td>
</tr>
<tr>
<td>Compensation Less Than Average Squared</td>
<td>.000167***</td>
<td>.0002</td>
<td>.000126</td>
</tr>
<tr>
<td>Employee Ownership Dummy</td>
<td>.0117</td>
<td>.0107</td>
<td>-.0092</td>
</tr>
<tr>
<td>Employee Ownership Stake Over Pay</td>
<td>.0217**</td>
<td>.0095</td>
<td>.0031</td>
</tr>
<tr>
<td>Employee Ownership Stake Over Pay Squared</td>
<td>-.0027</td>
<td>.0018</td>
<td>-.0063</td>
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<tr>
<td>Profit Sharing Dummy</td>
<td>-.0052</td>
<td>.0113</td>
<td>-.0275</td>
</tr>
<tr>
<td>Profit Sharing Over Pay</td>
<td>.2327***</td>
<td>.0682</td>
<td>.0990</td>
</tr>
<tr>
<td>Profit Sharing Over Pay Squared</td>
<td>-.2180**</td>
<td>.0751</td>
<td>-.3653</td>
</tr>
<tr>
<td>Stock Options Dummy</td>
<td>.0127</td>
<td>.0219</td>
<td>-.0301</td>
</tr>
<tr>
<td>Stock Options</td>
<td>1.1e-06</td>
<td>9.2e-07</td>
<td>6.1e-07</td>
</tr>
<tr>
<td>Stock Options Squared</td>
<td>-.57e-12</td>
<td>3.8e-12</td>
<td>-1.3e-11</td>
</tr>
<tr>
<td>Training Dummy</td>
<td>.0964***</td>
<td>.0078</td>
<td>.0811</td>
</tr>
<tr>
<td>Training Hours</td>
<td>.0011***</td>
<td>.0001</td>
<td>.0008</td>
</tr>
<tr>
<td>Training Hours Squared</td>
<td>-8.8e-07***</td>
<td>1.6e-07</td>
<td>-1.2e-06</td>
</tr>
<tr>
<td>Job Security</td>
<td>.3871***</td>
<td>.0180</td>
<td>.3517</td>
</tr>
<tr>
<td>Supervision</td>
<td>.0193*</td>
<td>.0109</td>
<td>-.0021</td>
</tr>
<tr>
<td>Participation</td>
<td>.3279***</td>
<td>.0174</td>
<td>.2937</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.3784</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Adj. R^2$</td>
<td>0.3748</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N$</td>
<td>20,206</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < .10, two-tailed test  
**p < .05, two-tailed test  
***p < .01, two-tailed test
Compensation Greater Than Average (CGTA) is compensation greater than industry average, expressed as a percentage of industry average. Thus, CGTA = 5 means a 5% increase in compensation relative to the industry average. Industry average is assumed to be $100,000 a year in the model.

To predict the change in job satisfaction when compensation changes, the statistically significant coefficients of CGTA and CGTA Squared are used.

\[
\text{Change in Job Satisfaction} = 0.0063 \times \text{CGTA} - 0.0000065 \times \text{CGTA}^2 \quad (8.2)
\]

Thus, a 5% compensation increase relative to the industry average leads to \(0.0063 \times 5 - 0.0000065 \times 25 = 0.029\) units increase in job satisfaction.

A similar procedure is performed for compensation that is less than the industry average. Figure 8.2a shows the predicted regression result. On the horizontal axis, 50% means total compensation worth 50% of industry average. The vertical axis shows the change in job satisfaction index, with zero meaning there is no change in job satisfaction.

Figure 8.2a: Effect of Financial Compensation as % of Industry Average on Job Satisfaction (#1)
At 100% of industry average, the change in job satisfaction is zero. At 150%, the job satisfaction index is increased by 0.15 units on a scale of 1 to 4, and at 50%, job satisfaction decreases by 0.37 units. What is interesting is the changing slope, where for compensation larger than 100%, the effect on job satisfaction increases at a decreasing rate, signifying that as people are paid with higher compensation, the incremental increase in compensation makes people more satisfied by a lesser magnitude. On the other hand, when people are paid less than average, a sharp drop in job satisfaction occurs. The rate of reduction in job satisfaction decreases as one lowers the compensation. The kink at 100% is similar to the well-documented prospect theory (Kahneman and Tversky 1979).

Figure 8.2b shows the 95% confidence interval of the effect of financial compensation on job satisfaction. It is predicted using the values from the upper and lower bounds of the confidence interval in Table 8.1. The red line is the upper bound and the green is the lower bound. As expected, the farther away from 100% of industry average, the wider the confidence interval, signifying the greater the uncertainty. It is worth noting that the red line curves up as compensation decreases to less than 65% of industry average. This is due to the quadratic equation in the regression model. It means people with 50% compensation see their job satisfaction decrease by a lesser amount than the ones with 65% compensation. This is not realistic. Alternatively, I assume that, for compensation less than 65%, the change in job satisfaction stays constant at the value of 65% compensation for the upper bound. A similar assumption is imposed for the green line passing 130% compensation. For compensation greater than 130%, the increase in job satisfaction is assumed to stay constant at the value of 130% compensation for the lower bound. Figure 8.2c shows the revised confidence interval. A sensitivity analysis using the 95% confidence interval is presented in Chapter 12.
Figure 8.2b: 95% Confidence Interval of the Effect of Financial Compensation as % of Industry Average on Job Satisfaction

Figure 8.2c: 95% Confidence Interval of the Effect of Financial Compensation as % of Industry Average on Job Satisfaction
8.4 Psychological Ownership

8.4.1 Effect of Employee Ownership on Job Satisfaction

Figure 8.3a shows the effect of employee ownership stake as a percentage of pay on job satisfaction (#2 in Figure 8.1). This is based on the same specification in equation 8.1 that includes a dummy variable for any employee ownership stake along with linear and squared terms for size of stake. Employee ownership stake is the value of stock held in different plans by employees divided by base pay plus overtime. We see there is a jump of job satisfaction at 1% and a steady increase at a diminishing rate until 200%, the maximum in the available data. The jump can be interpreted as people gaining psychological satisfaction and feeling like owners as long as some stock is granted. Once an employee has stock, the higher the value of the average stock each employee owns, the higher her job satisfaction is. For example, if the stock price increases and makes the average stock owned by each employee worth 200% of her salary, this increases her job satisfaction by 0.045 units more than if she has no stock at all.

Figure 8.3a: Effect of Employee Ownership Stake as % of Pay on Job Satisfaction (#2)
One limitation of the NBER dataset is that the maximum data available on employee ownership stake cuts off at 200% of pay. It is unrealistic to assume that any stake greater than 200% has the same effect as that of 200%. Given that there is no data available beyond 200%, the function is extrapolated to asymptotically reach 0.05 as employee ownership stake reaches 300% and beyond (see the circled line in Figure 8.3b). That means when the average stock owned by each employee is worth 3 times their salary, their job satisfaction increases by 0.05 units. The asymptotic assumption is justified on the ground that there must be a limit to the psychological effect of employee ownership stake: people cannot be infinitely happier as the value of their stock increases indefinitely. Even the founder who owns the whole stake at the beginning has a limit to satisfaction.

Figure 8.3b: Extrapolated Effect of Employee Ownership Stake as % of Pay on Job Satisfaction (#2)
8.4.2 Effect of Profit Sharing on Job Satisfaction

Figure 8.4 shows the effect of profit sharing as a percentage of pay on job satisfaction (#3 in Figure 8.1). As with the employee ownership stake, this is based on the same specification in equation 8.1 that includes a dummy variable for any profit sharing along with linear and squared terms for size of profit sharing. Profit sharing as percent of pay is the total dollar value of the payment(s) one received as bonuses in the most recent year divided by base pay plus overtime. As profit sharing % increases, job satisfaction increases at a decreasing rate.

Figure 8.4: Effect of Profit Sharing as % of Pay on Job Satisfaction (#3)
8.5 Job Satisfaction Effects

8.5.1 Effect of Job Satisfaction on Turnover Rate

One difficulty of using the NBER data and self-reported survey data in general is how to translate the regression results into the table functions when some of the data series are not the exact variables in the model but related to them. For example, the turnover rate in the model is the actual turnover rate, the percentage of people leaving per year. The closest measure from the NBER data is Turnover Intentions, reporting how likely people are to look for a job with another organization within the next twelve months. Translating turnover intentions into an actual turnover number is difficult to do; studies have shown they are highly correlated, but there are no good representative studies that I know of to make an exact translation. In the NBER data, “already looking” + “very likely looking” is used as a measure of the turnover rate. This averages 12.4% across the sample, which is similar to the average actual turnover rate reported by companies to the Great Places to Work Institute. This encourages confidence that the self-reported data is a good proxy for actual turnover. Further studies could collect and use the actual turnover rate to estimate the table function.

Figure 8.5 shows the effect of job satisfaction on turnover rate (#4 in Figure 8.1). Ordered probit is used to predict the probability of “already looking” + “very likely looking” for the turnover rate measure. The result shows that job satisfaction is a powerful predictor of turnover rate – the lower the job satisfaction, the higher the turnover rate. People vote with their feet: the less happy they are, the more likely they are to choose to leave the company.

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3 In a forthcoming study by Douglas Kruse and Joseph Blasi, the major regression results using the NBER dataset were confirmed using a dataset comprising about 300,000 employee surveys and company data from the 800 companies that applied for the 100 Best Companies to Work for in America designation of Fortune magazine. In this study the outcomes such as turnover, employee ownership and profit sharing were supplied by the companies and were not self-reported data.
8.5.2 Effect of Job Satisfaction on Willingness to Work Hard

Job satisfaction is another powerful predictor of willingness to work hard. The question for willingness to work hard is “To what extent do you agree or disagree with this statement? ‘I am willing to work harder than I have to in order to help the company I work for succeed’” (1-5 scale, 1=strongly disagree, 5=strongly agree). Ordered probit is used to predict the probability of “strongly agree” or “agree” for the willingness to work hard measure.

One way to translate the willingness to work hard measure into the actual work time is to use the multiplicative function:

\[ \text{Workweek} = \text{Normal Workweek} \times \text{Effect of Job Satisfaction on Workweek} \times \text{Effect of Work Pressure on Workweek} \]
Actual workweek is determined by the normal workweek times the effects from job satisfaction and work pressure. Figure 8.6 shows the effect of job satisfaction on willingness to work hard (#5 in Figure 8.1). It shows when job satisfaction is at its normal scale 3, its effect on willingness to work hard equals 1, which means people work at the normal workweek of 50 weeks per year (if effect of work pressure on workweek = 1). When job satisfaction decreases below 3, people are less willing to work hard and thus reduce their workweek. When people are more satisfied than normal, they are willing to work for a longer time, since they enjoy the work.

**Figure 8.6: Effect of Job Satisfaction on Willingness to Work Hard (#5)**

![](image)

8.5.3 **Effect of Job Satisfaction on Employee Productivity**

Figure 8.7 shows the effect of job satisfaction on employee productivity. The higher the job satisfaction, the higher employee productivity is. The productivity effect is modeled as a multiplicative function as shown in section 9.3. When job satisfaction is at the reference level of 3 on a 1 to 4 scale, the employee productivity effect is neutral at 1.
When job satisfaction is higher than the reference, the productivity effect increases, and when job satisfaction is lower, the productivity effect decreases.

It is worth noting that aggregated employee evaluations of establishment productivity are used for the productivity measure since they are highly correlated with actual productivity measures in the NBER data. Figure 8.7 is based on a regression of establishment-level productivity on average establishment-level job satisfaction and its square and cube. The circles on two sides are based on judgment as there is no data available in those ranges. Sensitivity analysis is conducted to analyze how sensitive the assumption is in Chapter 11.

Figure 8.7: Effect of Job Satisfaction on Employee Productivity (#6)
9. EMPLOYEE PARTICIPATION

9.1 Causal Loop Diagram of Employee Participation

Employee participation is an important element of an HPWS and ownership culture (Rosen, Case and Staubus 2005; Rosen and Rodgers 2007; Kruse, Freeman and Blasi 2010). How does participation influence employee behavior and firm performance? Figure 9.1 shows a high-level causal structure of employee participation. There are two effects of participation effort. First, it increases employee productivity as the firm accumulates participation experience and builds up participation culture. Second, participation effort increases the employee education and coaching effort, thereby reducing the effective work effort available for real work. Under what condition does the long-term productivity gain outweigh the short-term work effort loss? This question is analyzed in Chapter 11. This chapter describes the model formulations of the employee participation sector. The subscripts for the equations are ignored for simplicity.

Data for this sector is based on interviews with researchers and consultants in the employee ownership field, and practitioners in employee-owned companies, as well as a review of the employee ownership literature (e.g., Rosen, Case and Staubus 2005; Rosen and Rodgers 2007; Kruse, Freeman and Blasi 2010). While the model attempts to capture the essence of the participation structure, it is important to note that this section is meant to be illustrative and not definitive. Unlike the employee ownership effects in Chapter 8, the functional forms and parameters in the participation sector are not based on quantitative regression analysis; they are based on qualitative interviews. Future work could estimate the functional forms described below using survey data on employee participation.

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4 I would like to thank Corey Rosen and Loren Rodgers at the National Center for Employee Ownership, Joseph Blasi and Douglas Kruse at Rutgers University, Mary Ann Beyster at the Foundation for Enterprise Development, Chris Mackin at the Ownership Associates, Anthony Matthews at the Beyster Institute, J. Robert Beyster and employees at Science Applications International Corporation, and participants at the 2009 and 2010 Beyster Fellowship Symposiums.
Figure 9.1: Causal Loop Diagram of Employee Participation
9.2 Participation Culture

Participation time is the number of work hours per year allocated to participation effort; this includes team work, problem solving groups and participation committees. As the firm spends more time on participation, employees’ participation experience builds up over time and is modeled as a co-flow structure (Sterman 2000). Thus, participation experience captures the time delay in building up a participation culture – it takes a sustained participation effort over time to accumulate the experience needed to establish a participation culture. Participation culture is modeled as an average participation experience per employee over a reference level. Thus, as the average employee’s accumulated participation experience reaches the reference level of 100 hours of average participation experience for each employee, the company participation culture index equals to 1 and signals a mature participation culture. Participation culture is a theoretical construct that captures the observation that it takes a certain sustained participation effort throughout the whole company over time to build the culture. One cannot build the culture with a one-time initiative. Participatory companies, such as W. L. Gore and Southwest Airlines, spend sustained effort in participation are cases in point.

\[
\text{Participation Effort} = \text{Participation Time} \times \text{Employees} \tag{9.1}
\]
\[
\text{Participation Experience} = \text{INTEGRAL} (\text{Participation Effort} - \text{Participation Experience Loss Rate from Quits} - \text{Participation Experience Loss Rate from Layoffs} - \text{Participation Experience from Forgetting}) \tag{9.2}
\]
\[
\text{Average Participation Experience} = \frac{\text{Participation Experience}}{\text{Employees}} \tag{9.3}
\]
\[
\text{Participation Culture} = \frac{\text{Average Participation Experience}}{\text{Reference Average Participation Experience}} \tag{9.4}
\]
9.3 Productivity Gain from Participation

The effect of participation culture on productivity is modeled as a nonlinear function, as shown in Figure 9.2. Before employee culture reaches the threshold level of 0.3 units, productivity effect is less than one, signaling the loss of productivity due to the learning curve in participation effort: it takes time for employees to learn initiatives such as the learning circle, problem solving group and open book management before they can become effective. However, once enough experience is accumulated to the point where participation culture passes 0.3 units, the productivity effect becomes greater than one – employees become more productive than without participation, as more innovations are generated through employee involvement.

Effect of Participation Culture on Productivity = Function for Effect of Participation Culture on Productivity [Participation Culture] \hspace{1cm} (9.5)

Productivity Effects = Effect of Participation Culture on Productivity * Effect of Employee Experience on Productivity * Effect of Employee Quality on Productivity * Effect of Job Satisfaction on Productivity \hspace{1cm} (9.6)

Effective Work Effort = Employees * Work Time * Productivity Effects \hspace{1cm} (9.7)
9.4 Work Effort Loss from Participation

For each unit of participation effort, one needs to allocate additional employee education and coaching effort to make it work. For example, one needs to provide employee education teaching people how the ownership plan works. In addition, it is important to train people in business literacy so they have the tools to think like entrepreneurs about company performance. These efforts are usually conducted through internal coaching from senior employees.

Employee education and coaching effort per unit of participation effort does not stay fixed; it varies with the firm’s participation culture. Figure 9.3 shows that as the firm builds up its participation culture, the fraction of education and coaching effort needed per participation effort decreases. There is less need to educate and coach as more employees accumulate experience in participatory management. People become familiar with the participatory culture and able to self-organize and manage the process.
Employee Education and Coaching Effort = Participation Effort * Effect of Participation Culture on Employee Education and Coaching Effort

\[ \text{Effect of Participation Culture on Employee Education and Coaching Effort} = \text{Function for Effect of Participation Culture on Employee Education and Coaching Effort} \]

\[ [\text{Participation Culture}] \]

Net Effective Work Effort = Effective Work Effort - Employee Education and Coaching Effort

\[ \text{Work Pressure} = \frac{\text{Desired Work Effort}}{\text{Net Effective Work Effort}} \]

Figure 9.3: Effect of Participation Culture on Employee Education and Coaching Effort

9.5 Participation Time

Managers decide how much time is allocated to participation. Participation time is modeled as the normal participation time multiplied by the effect of work pressure on participation time. Figure 9.4 shows that the higher the work pressure experienced by
managers, the less time they allocated to participation. This captures the observation that real work demand takes precedence over participation. When the work pressure is three times higher than the actual work effort (work pressure = 3), managers cut participation time to zero.

The variable sensitivity of participation time to work pressure captures the decision rule managers use to determine participation time. When the sensitivity = 1, managers decide according to the table function in Figure 9.4. When the sensitivity = 0, managers are not affected by work pressure and allocate fixed normal participation time.

Participation Time = Normal Participation Time * Effect of Work Pressure on Participation Time

\[ \text{Effect of Work Pressure on Participation Time} = 1 + \text{Sensitivity of Participation Time to Work Pressure} \times (\text{Function of Effect of Work Pressure on Participation Time} - 1) \]  

(9.13)
10. **BASE CASE ANALYSIS**

This chapter presents the business strategy, employee behavior and firm performance in the base case scenario.

10.1 **Business Strategy**

At the time of my field research, Alpha Inc. had $1 million working capital including founder capital and a government grant (Figure 10.1). Their technology was promising but was still at the early development stage and appeared it would need about three to four years to fully develop the product, with a payback period at around five years. Alpha Inc.’s sales cycle was long (about 1 year), as the customers were not familiar with this new technology. Significant direct sales effort was needed to move the potential customers through the prospect chain. Thus, with an early product development stage and long sales cycle, the firm planned to ask for venture capital (VC) financing to help it get through the “valley of death” (Figure 10.2).

The managers projected that Alpha Inc. would be able to attract two rounds of VC financing, first $4 million at year 1 to fund its product development and then $8 million at year 3 to fund its go-to-market strategy. Based on these initial conditions and assumptions, the model shows that, after burning cash for seven years, its working capital starts to go up (Figure 5a) because cash flow has turned positive (Figure 10.2). Years 0 to 7 in Figure 10.2 are the infamous “valley of death” where the firm needs sufficient injection of financing to help it return to cash-positive. A boost in financing is possible, thanks to an increasing sales volume starting from the first sale at year 5 and sufficient sales at year 7 to generate positive net income (Figure 10.3). It takes such a long time to turn cash-positive because Alpha is at an early product development stage and its product development and sales cycles are long. Alpha’s product starts out with 8 years of customer payback period (Figure 10.4), i.e., it takes 8 years of accumulated energy
savings from adopting Alpha’s product to cover the costs of purchasing the product. A payback period of 8 years is too long to be considered attractive for the customers.

Alpha’s initial strategy is to focus on product development by hiring engineers (Figure 10.5) to develop product features that would increase the energy savings their product offers and thereby shorten the payback period (Figure 10.4). Being mindful of the long sales cycle and the need to generate revenue, the firm begins to hire sales people, though fewer than engineers (Figure 10.5). Around year 5.5, the sales force surpasses the engineers, i.e., the sales force as a fraction of total employees passes 0.5 (Figure 10.6). This is because the firm has developed a good enough product, by switching from product development to a sales focus strategy after year 5.5, that the firm is able to generate an increasing amount of sales: enough to turn cash-positive by year 7.

At around year 8, Alpha begins to reduce its sales fraction gradually and shift towards growing the engineering force (Figure 10.6). This is because each sale requires ongoing customer service support performed by service engineers. To maintain high customer service quality and keep earning service fees, the firm gradually shifts to a service-focused strategy by increasing the fraction of service engineers.

Figure 10.1

![Figure 10.1](image1)

Figure 10.2

![Figure 10.2](image2)
The graphs above have a time horizon of 15 years, which is too short to saturate the market. The addressable market is still much larger than the installed base by year 15 (Figure 10.7). The addressable market increases as the product becomes more attractive over time due to shorter payback period. The drop from year 7.5 to 9 is caused by the shortage of customer service as sales volume increases rapidly and it takes time to hire and train service engineers (Figure 10.8). As customer support increases over time, the addressable market expands again after year 9. Note that after year 8, all engineering effort is allocated to customer support, with no product development. This is because in this base case scenario, no new entrant to compete against the firm is assumed. The firm has developed a good product that needs no further development, thus freeing up its engineers to focus on customer support. The assumption of no entry of competitors is unrealistic; hence a sensitivity analysis of competitive pressure from new entrants is presented in Chapter 12.

While the model cannot perform a historical fit as there is no time-series data available from Alpha Inc., the stylized pattern of behavior shown in the base case scenario is consistent with the entrepreneurship literature: the valley of death dynamics; the need for several rounds of VC financing in a long product development and sales cycle industry; the product life cycle of going from infancy, growth, maturity to decline; and the strategic shifting from product development at the early stage to a sales-focused strategy in the growth stage and service model at the mature and decline stage (Roberts 1991; Gartner et al. 2004; Kuratko and Hodgetts 2006). Future work could calibrate the model to a clean tech startup with a long enough time-series dataset.

10.2 Employee Behavior

The base case described here is the scenario where the salary is the same as the industry average and there are no stock options, stock grants, profit sharing, or participation. This is the scenario of a non-shared capitalism, non-employee-owned company. Given that there is no extra compensation besides average salary, plus the average workweek is very long due to high work pressure from working in a startup (Figure 10.9), job satisfaction is consistently below the reference value of 3, as people are burned out (Figure 10.10). The
reputation of there being low job satisfaction deters high-quality people from joining the company and, as a result, average employee quality is below the reference value of 1 (Figure 10.11). Quarterly turnover hovers around 3% of total employees (Figure 10.12). Rookie employees as a fraction of total employees increases when there are new hires due to the injection of venture capital at years 1 and 3 (Figure 10.13). After year 8, the company becomes cash-positive and starts hiring again. The higher the rookie fraction, the lower the average employee experience, as there are more inexperienced rookies in the workforce mix (Figure 10.14). As shown in Figure 6.4, employee productivity is driven by job satisfaction, employee quality and employee experience. Productivity increases slightly over time as employee experience accumulates, despite the negative effects from job satisfaction and employee quality (Figure 10.15). If the firm adopts other shared capitalism policies, one can expect its job satisfaction and productivity to go up significantly in comparison to this base case scenario.

Figure 10.9

Average Workweek

Figure 10.10

Job Satisfaction

Figure 10.11

Average Employee Quality

Figure 10.12

Quarterly Turnover as % of Total Employees
10.3 Financial Performance

The model also has a detailed financial sector that illustrates various financial performance indicators. Figure 10.16 shows that the cumulative profit goes from negative to zero at year 12.5, and thereafter increases exponentially. Market capitalization starts to jump up after year 7 when the firm starts to make a profit, and is calculated as expected present value of net income (Figure 10.17). Shares outstanding increases at years 1 and 3 as new shares are issued to the venture capitalists for their investments (Figure 10.18). Stock price equals the market capitalization divided by the total shares outstanding (Figure 10.19). The founder’s ownership stake shrinks from 100% to 41% at year 1 and 18% at year 3, while the total VC ownership increases from 0% to 59% to 82% (Figure 10.20). There is no employee ownership or IPO in this scenario. Founder’s net worth equals her number of shares times stock price. It reaches
$40 million by year 15 whereas the total VC net worth reaches $186 million (Figure 10.21).
To see the main causal structure described above, Figure 10.22 shows the causal linkages of the key variables. It presents the base case scenario with salary at 100% industry compensation and no shared capitalism policy. Figure 10.23 shows the same causal loop diagram of salary effect in words, without the behavior-over-time graphs.
Figure 10.23: Causal Loop Diagram of Salary Effect
11. POLICY ANALYSIS

The base case described above is the non-shared-capitalism company where there are neither stock options, stock grants, profit sharing, nor participation. In this chapter, I will analyze the dynamic effects of different levels of salary, stock grants, profit sharing and participation on employee behavior and firm performance.

11.1 Stock Grants

11.1.1 Low to Medium Levels of Stock Grants

To test the effect of employee ownership through stock grants, I create a variable called Annual Stock Grants Value as Percentage of Industry Compensation (ASGV). ASGV captures the policy of compensating employees by giving them an ownership stake in the company. The value of stock granted to each employee annually is modeled as a percentage of industry average compensation. For example, suppose the industry compensation is $100,000 per person per year. If one would like to give stock grants worth 10% of the industry compensation ($10,000 per person per year), and the internal stock price is $10 per share at the time stocks are granted, each employee would receive 1000 shares per year.

Stock grants help conserve cash, recruit employees, reduce turnover, and motivate people to work harder. One might compensate for salaries lower than the industry norm by giving each employee an ownership stake in the firm through stock grants. However, granting stock to employees dilutes everyone’s (including the founder’s) ownership. How should one decide whether or not to grant stock to employees? How much value motivates employees without too much dilution? When is the right time to award the stock and for what purpose? These are interesting theoretical questions for researchers and crucial practical questions for entrepreneurs.

Figure 11.1 shows three policy runs: average stock grants value as 0% (blue), 10% (red) and 20% (green) of industry compensation, holding salary constant at 100% industry
compensation. As ASGV increases from 0% to 10% and 20%, we see employee ownership percentage increasing from 0% to 14% and 24% by year 15. Despite the increase in employee ownership, the founder’s net worth actually increases from $45M to $88M and $90M, respectively, at year 14 (two graphs on the left). That is, the more wealth is shared with employees, the more wealth is created for the founder.

Why is that? The underlying causal loop diagram is shown in Figure 11.2. Figure 11.1 shows the selected variables from the causal loop diagram. The eight graphs in the middle form the R2 loop, with the two graphs on the right forming the R1 loop. The key insight is that granting employees shares closes the employee ownership loop R2. When there are no stock grants (blue), there is no feedback from how the company is performing (stock price) to the employee behavior, since they are paid a fixed salary without an ownership stake. As a result, the employee’s job satisfaction stays relatively flat, despite the company starting to generate positive net income and the stock price rising from $1 to $10 at year 8 (blue).
Figure 11.1: Annual Stock Grant Value as Percentage of Industry Compensation: 0% (Blue), 10% (Red), 20%.
Figure 11.2: Causal Loop Diagram of Employee Ownership Effect
However, when ASGV is 10%, the employee ownership loop R2 is closed and job satisfaction jumps up along with the stock price (Figure 11.1). Employees are now part owners and firm performance feeds back to their behavior. Productivity and effective work effort go up, which increases quarterly sales, net income and working capital. The improved financial performance allows the firm to expand its employee workforce and further increase effective work effort, sales, net income and so forth. Stock grants close the R2 loop and trigger the R1 loop in a virtuous cycle, which in turn propels the R2 loop further in a virtuous direction. This interaction of two reinforcing loops causes the firm performance to increase exponentially over time, as seen in the widening wedge between the red and blue lines.

**Proposition I (Productivity Gain of Employee Ownership):** Employee ownership closes the reinforcing feedback loop from firm performance to employee behavior and generates additional productivity gain. Given appropriate conditions, higher stock price increases employees’ stock value, driving up job satisfaction, attracting better employee quality and reducing turnover. These, in turn, create additional productivity gain, which increases net income and stock price further. At the same time, higher net income enables hiring more workforce, which increases work effort, revenue and net income further. Thus, more wealth is shared through broad-based employee ownership; and more wealth is created, given the appropriate conditions.

Notice that, as ASGV increases from 10% (red) to 20% (green), stock price (and thus founder’s net worth) increases as well, though at a lower magnitude than when ASGV goes from 0% to 10% (Figure 11.1). This is caused by a diminishing returns of employee ownership effect. As employee ownership stake increases, the marginal increase in job satisfaction and productivity decreases over time. This is caused by the effect of financial compensation on job satisfaction, which increases at a decreasing rate for compensation greater than the industry compensation (Figure 8.2a). Consequently, productivity also increases at a diminishing rate until it reaches its maximum. Financial performance still increases as employee ownership stake increases, though at a diminishing rate.
Proposition 2 (Diminishing Returns of Employee Ownership): There is a diminishing returns of employee ownership effect. The effect of additional employee ownership stake increases job satisfaction, employee productivity, and firm performance at a diminishing rate.

11.1.2 Very High Levels of Stock Grants

Given that an additional employee ownership stake motivates employees and increases firm performance, is greater employee ownership better? Should the founder give employees as much ownership as possible? The answer depends on one’s measure of performance. Figure 11.3 shows policy runs with ASGV as 0% (blue), 50% (red) and 100% (green) of industry compensation. For sales, net income and market capitalization, the higher the stock grants, the higher their performance – though it increases at a diminishing rate, as explained earlier.

If one looks at stock price and founder’s net worth, their values actually decrease as ASGV increases from 50% (red) to 100% (green). This is due to the dilution effect of employee ownership. As more shares are issued to employees through stock grants, stock price decreases as total shares outstanding increase. Even though the market capitalization keeps increasing due to productivity gains from employee ownership, the magnitude of increase is outweighed by the dilution of additional shares. As a result, stock price can decrease when the dilution effect outweighs the productivity gain.

This can be explained through the causal loop diagram in Figure 11.2. Granting employees shares has two effects on stock price: productivity gain and dilution effects. Employee shares, firstly, create additional productivity gain and increase stock price by closing the employee ownership R2 loop (blue) and, secondly, dilute ownership by increasing total shares, which lowers stock price and the founder’s net worth (purple). The two combined effects determine the change in stock price.
Proposition 3 (Dilution Effect of Employee Ownership): Employee ownership has two effects on stock price: productivity gain and dilution effects. First, it creates additional productivity gain and increases stock price by closing the employee ownership loop. Second, it dilutes ownership by increasing total shares, which lowers stock price and founder’s net worth. The two combined effects determine the change in stock price. When too much ownership is granted (past a certain threshold), the dilution effect can outweigh the productivity gain, thereby lowering the stock price and the founder’s net worth.
11.1.3 Zero to High Levels of Stock Grants

When salary is fixed at the market average, how do different levels of stock grants influence firm performance? Figure 11.4 shows the market capitalization at year 15 under different constant levels of ASGV and 100% salary. When ASGV is zero, market capitalization at year 15 is $300 million. As the level of ASGV increases, market capitalization at year 15 increases. With 150% ASGV, market capitalization reaches $900 million by year 15. This is due to the productivity gain effect stated in Proposition 1.

The higher the level of ASGV, the less the incremental increase in market capitalization for every additional increase in ASGV. This demonstrates the diminishing return effect stated in Proposition 2. The productivity gain of employee ownership diminishes as the stock grants level increases. Thus, as more wealth is shared, more wealth is created, but at a diminishing rate.

Figure 11.4: Market Capitalization at Year 15 under Different Stock Grant Levels
How about founder’s net worth? Figure 11.5 shows founder’s net worth at year 15 under various levels of ASGV. The base founder’s net worth when there is no stock grant is $55 million at year 15. As the level of ASGV increases, founder’s net worth increases and reaches its peak when ASGV is 20% of industry compensation. It decreases steadily as ASGV passes 20%. This is due to the dilution effect stated in Proposition 3. Figure 11.6 shows the ownership percentages of founder, VC and employees at year 15 under different levels of ASGV. As the level of ASGV increases, more dilution occurs in founder’s (blue) and VC’s (green) ownership. This is caused by the increase in employee ownership (red).

It is worth noting that although founder’s net worth starts to decrease passing 20% ASGV, it still outperforms the base case of $55 million when there is zero stock grant. Only when ASGV is greater than 90% do we see founder’s net worth underperform the base case. This is because the dilution effect dominates the productivity gain, such that even though the total pie (market capitalization) increases with higher ASGV, the diminishing incremental increase in market capitalization is not enough to offset the loss in ownership share due to dilution. When too much ownership is granted (past a certain threshold), the dilution effect can outweigh the productivity gain, thereby lowering the founder’s net worth.
Figure 11.5: Founder’s Net Worth at Year 15 under Different Stock Grant Levels

![Graph showing Founder’s Net Worth at Year 15 under Different Stock Grant Levels.](image)

Figure 11.6: Ownership Percentage at Year 15 under Different Stock Grant Levels

![Graph showing Ownership Percentage at Year 15 under Different Stock Grant Levels.](image)
11.1.4 Timing Effect: Pre-growth vs. Growth Period Grants

The timing of stock grants is another critical decision. When should one give out stock? Should one grant stock at the early cash-negative pre-growth stage or at the later cash-positive growth period? What is the dynamic tradeoff between productivity gains and dilution effects at different periods? Figure 11.7 shows three policy runs of awarding ASGV at 20% of industry compensation at three different periods: zero period (blue), cash-negative pre-growth period year 0-7 (red), and cash-positive growth period year 8-15 (green). First of all, no matter what the timing is, granting stocks generates higher net income and stock price than granting no stock at all. Granting no stock (blue) is the worst performing in all graphs.

Second, the cash-negative pre-growth period (red) produces higher market capitalization than the cash-positive growth period (green). This is because granting stock at the early stage allows the firm to capitalize the productivity gain effect early on and amplify it at the growth stage. This is demonstrated in the job satisfaction and productivity graphs where the red line is higher than the blue line, both from years 1 to 7 when the stock is granted and from years 7-15 when no stock is granted. The reason productivity increases despite no new stock being granted is because the value of the stock of previously awarded shares increases as stock price increases in the growth period. Employees are able to share part of the wealth created from the early stage, which boosts their job satisfaction and productivity in the later period. The R2 loop is closed early on and allows the R1 and R2 loops to mutually reinforce and amplify each other over time. Despite no new stock being granted in the growth period (a flow concept), the stock granted in the pre-growth stage has closed the R2 loop earlier and will continue to do so for employees who own the stock (a stock concept). The early capitalization and later amplification effects explain why market capitalization is much higher for the pre-growth period grants (red) than the growth period grants (green).

Note that there is a subtle caveat to this analysis. The current model does not keep track of who owns stock or not: it calculates the average share outstanding for all employees, and assumes the averaged impact applies to all employees. Future work could distinguish
the ones with stock versus the ones without, and the new versus old employees, to study the differential impact on employee behavior and firm performance.

What about stock price and the founder’s net worth? Do pre-growth-period grants always yield higher values than the growth-period grants? It depends on the dynamic tradeoff between productivity gains and the extent of dilution. To grant stock worth 20% of industry compensation at the early stage when the stock price is very low, the firm needs to issue many more shares to the employees than in the growth stage, when the stock price is high. This can be seen in the employee ownership graph where the pre-growth-period grants result in 22% at year 15 as opposed to the merely 2% from the growth-period grants.\(^5\) The higher volume of newly issued employee shares increases the total shares outstanding, thus lowering the stock price\(^6\). Given that the founder has the same 1 million shares, the founder’s ownership becomes diluted and her net worth follows the same trajectory as the stock price. Since the dilution rate under ASGV at 20% of industry compensation is not very strong, the founder’s net worth is still higher than with growth-period grants and is surpassed only at year 14.

Figure 11.8 shows similar runs with ASGV at 50% of industry compensation as opposed to 20% for the three different periods. Because of the much higher volume of stock grants, the employee ownership share reaches 41% at year 15 for the pre-growth period grants and 5% for the growth-period grants. The dilution effect is so strong that founder’s net worth from the pre-growth-period grants (red) is only slightly higher than with the growth-period grants (green) before it is surpassed at year 11.5 – a much earlier date than year 14.

**Proposition 4 (Timing Effect of Employee Ownership):** Stock granted at the cash-negative pre-growth period closes the employee ownership loop early on and enables the firm to capitalize on productivity gains in the early stage and to amplify them in the later period, thereby producing higher net income and market capitalization than the stock

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\(^5\) The reason the red line in employee ownership graph gradually reaches to 23% is due to the 3 year vesting period of stock grants assumed in the model. Thus, after stopping the granting of stocks at year 7, all the non-vested grants from the past gradually become fully vested later on.

\(^6\) Stock price (S/share) = Market capitalization ($) / Shares outstanding (shares)
granted at the cash-positive growth period. However, higher dilution occurs with the pre-growth-period grants, as more shares need to be issued, given the low firm valuation at the pre-growth stage, which depresses stock price at the later period. The extent of pre-growth versus growth-period grants’ impact on stock price and the founder’s net worth depends on the dynamic tradeoff between productivity gains and the extent of dilution overtime.
Figure 11.7: Timing of Awards\% Annual Stock Grant Value at 20\% of Industry Compensation: Zero Period

Zero Period Year 0-7 (Red), Cash-Positive Growth Period Year 8-15 (Green)

Blue: Cash-Negative Pre-Growth Period Year 0-7 (Red), Cash-Positive Growth Period Year 8-15 (Green)
Figure 11.8: Timing of Retaining Annual Stock Grant Value at 50% of Industry Average: Zero Period (Blue), Cash-Negative Pre-Growth Period Year 0-7 (Red), Cash-Positive Growth Period Year 8-15 (Green)
11.2 Stock Options

Stock options differ from stock grants in that stock grants give shares outright to employees, whereas stock options give the employees the right to purchase stocks at a predetermined strike price. Options may be exercised when the stock price is greater than the strike price. The employees profit from the difference, which motivates them to improve stock price through their work effort. How do stock options influence employee behavior and firm performance? To analyze the dynamic effect of stock options, I created a variable called Annual Stock Options per Employee as a Basis Point of Total Shares (ASO). ASO captures the policy of compensating employees by offering them annual stock options. The number of stock options is modeled as the basis point of the total shares outstanding. Thus, a policy of 5 basis points of ASO means granting each employee a number of options worth 0.0005 of total shares. For instance, if the firm starts with one million shares, each employee will receive 500 options per year. The model assumes a vesting period of 3 years.

Figure 11.9 shows four policy runs where ASO equals 0 basis points (blue), 5 basis points (red), 10 basis points (green) and 15 basis points (grey). Notice that the higher the ASO, the higher the job satisfaction, net income, stock price and founder’s net worth. This is because stock options, like stock grants, also close the employee ownership loop R2 in Figure 11.2. The difference, however, is that employee job satisfaction increases only after options are “in the money” (stock price exceeds the strike price), starting in year 7. The employee ownership loop starts to kick in when options are in the money and are exercised after the three-year vesting period.

Notice that in the employee ownership percentage graph, employee ownership gradually reaches 15% under all three ASO policies. This is because there is an assumption of 15% option pool in the model (commonly observed in startups). As a result, the amount of ASO the firm is able to award decreases when the total option pool reaches 15%. Employee ownership increases faster with 15 basis points ASO (grey) than 10 (green) or 5 basis points (red), as more options are issued to employees earlier. The higher ASO
strengthens the employee ownership loop and leads to higher firm performance, though at a diminishing rate.

**Proposition 5 (Dynamic Effect of Stock Options):** The dynamic effect of stock options is similar to that of stock grants, though with some subtle differences. Like stock grants, stock options close the employee ownership loop by creating a feedback linkage from firm performance to employee behavior. However, the virtuous reinforcing effect kicks in only when stock prices exceed strike prices. The more options that are granted, the stronger the employee ownership loop gain, which leads to higher firm performance, given the right strategy. The increase in firm performance increases at a diminishing rate.
11.3 Profit Sharing

Profit sharing is another commonly practiced form of shared capitalism modes of compensation. How much should one share profits with employees? The higher the profit sharing (assuming profitability), the more motivated are the employees, but the lower the returns to shareholders. Yet how do different magnitudes of profit sharing influence employee behavior and firm performance?

Figure 11.10 shows four policy runs of profit sharing as different percentages of net income: 0% (blue), 5% (red) and 10% (green). First of all, it is obvious that profit sharing only begins to have an impact when net income turns positive after year 8. Profit sharing is a useful motivational tool only when the company escapes the valley of death and enters the growth stage.

Second, as profit sharing percentage increases from 0 to 5% to 10%, job satisfaction, productivity, net income, market capitalization, stock price and founder’s net worth all increase, though at a diminishing rate. These variables increase because profit sharing closes the feedback loop R3, which connects net income to financial compensation through profit sharing (Figure 11.11). Therefore, how the firm performs matters directly to employees, since part of their compensation depends on it. This scenario creates additional incentive for employees to work harder and increase their productivity, and leads to higher net income, average profit sharing, market capitalization and stock price. All stakeholders (employees, founders and shareholders) are better off as a result. When done in this range, profit sharing is another tool to create wealth by sharing wealth.
Figure 11.10: Profit Sharing as Percentage of Net Income: 0%, 3%, 5%, 7%, (Red) and 10%, (Green)
Does this mean the higher the profit sharing the better, and that one should share as much profit as possible? Figure 11.12 shows three policy runs with 0% (blue), 50% (red), and 70% (green) profit sharing. With 70% profit sharing (green), average profit sharing is around $150,000 per person per year at year 8, this increases job satisfaction and productivity by large amounts. However, effective work effort actually falls below the zero profit sharing case (blue). This is due to the lower number of employees hired.

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7 The reason productivity rises sharply is due to multiple effects — job satisfaction, employee quality and employee experience — working concurrently. High profit sharing drives up job satisfaction, attracts high-quality employees and lowers turnover, which conserves employee work experience. As a result, productivity increases sharply over time in a high profit sharing setting.
because working capital and net income decrease after profit sharing. After expensing profit sharing, net income falls far below the 0% case. This creates an additional balancing loop B1, as lower net income constrains the firm’s hiring budget and reduces its workforce more than otherwise, which decreases sales and net income further than the 0% case.

At 50% profit sharing (red), the increase in productivity almost exactly offsets the loss in workforce, which makes the effective work effort the same as the base 0% case (blue). For profit sharing greater than 50%, the balancing loop B1 dominates the reinforcing loop R3, and the system tips over to lower financial performance, as described earlier. Notice that market capitalization and stock price lines shift downward as the profit sharing percentage passes the threshold. There appears to be a tipping threshold where profit sharing’s impact on work effort and firm performance turns from positive to negative.

**Proposition 6 (Benefits of Profit Sharing):** An increase in profit sharing as a percentage of net income before a certain tipping threshold increases job satisfaction, productivity, net income, market capitalization, stock price and founder’s net worth at a diminishing rate. Profit sharing causes productivity to increase through higher job satisfaction, better employee quality, and longer work experience from lower turnover.

**Proposition 7 (Tipping Threshold of Profit Sharing):** Once the profit sharing percentage surpasses the tipping threshold, the reduction in net income after expensing profit sharing limits the resources available to expand the workforce. The workforce reduction outweighs the productivity gain from profit sharing, and profit sharing’s influence on work effort and firm performance turns from positive to negative.
Figure 11.12: Profit Sharing as Percentage of Net Income: 0% (Blue), 60% (Red), 70% (Green)
11.4 Participation

All the analyses above assume there is no employee participation. Studies show that employee participation is an important element of a HPWS and ownership culture (Rosen, Case and Staubus 2005; Rosen and Rodgers 2007; Kruse, Freeman and Blasi 2010). Formulation of the participation structure was described in Chapter 9. Figure 9.1 is reprinted below to show the causal loop diagram of employee participation.

Figure 9.1: Causal Loop Diagram of Employee Participation (Reprinted)
There are two main effects of participation effort. First, it increases employee
productivity as the firm accumulates participation experience and builds up participation
culture. Second, participation effort increases the employee education and coaching
effort, thus reducing the effective work effort available for real work. Under what
condition does the long-term productivity gain outweigh the short-term work effort loss?
This section analyzes the dynamic effects of participation and its interactions with other
shared capitalism practices.

11.4.1 Low Participation Effort

As mentioned in section 9.5, the variable sensitivity of participation time to work
pressure captures the decision rule managers use to determine participation time. When
the sensitivity $= 1$, managers decide according to the table function in Figure 9.4. When
the sensitivity $= 0$, managers are not affected by work pressure and allocate a fixed
normal participation time. Figure 11.13 shows two policy runs with no participation
(blue) and low participation (red). No participation is the case when participation time
equals zero hours per year. Low participation is the case when managers’ participation
policy is highly sensitive (0.9) to work pressure. Given that the startup company
experiences high work pressure, a high sensitivity of 0.9 units means a low level of
participation time of 10 hours per year.

The consistently low participation time causes the firm’s financial performance (net
income, stock price and working capital) to fall below that of zero participation. This is
because the low participation time is insufficient to build up enough participation culture
(graph in the middle) to trigger productivity gain. As shown in Figure 9.2, before
participation culture reaches a tipping threshold of 0.3 units, there is productivity loss due
to effects of the learning curve in participation effort – it takes time for employees to
learn initiatives such as the learning circle, problem solving group and open book
management before they become effective. Thus the productivity gain loop R2 in Figure
9.1 has not kicked in to outweigh the work effort loss from employee education and
coaching effort, loop B1. As a result, low participation actually makes the firm
performance worse than with no participation.
It is worth noting that the number 0.3 as the tipping threshold is a theoretical construct. The actual number is an empirical question and needs further research to develop exact measurements of participation culture. Whatever the exact number is, the concept of a tipping threshold of participation culture where productivity gain starts to kick in is consistent with practitioners’ experience. This analysis shows the dynamic effects of participation culture on employee productivity and firm performance.
11.4.2 Medium and High Participation Effort

Figure 11.14 shows three policy runs: no participation (blue), medium participation (red) and high participation (green). Medium participation is the case when sensitivity = 0.7, which results in 30 hours per year of participation time. High participation is when sensitivity is set to zero – managers adopt a fixed participation policy of 100 hours per year, regardless of the work pressure. The persistence of high participation effort (green) pays off in the long run as the firm builds up a strong participation culture that causes productivity to increase beyond the zero participation case (blue). As a result, the firm’s performance is higher when managers adopt a sustained participation effort independent of the work pressure.

When managers become sensitive to work pressure and adopt medium participation effort (red), the impact on firm performance is minimal, as productivity gain is washed out by work effort loss. It takes time to build up participation culture. Medium participation effort builds up participation culture more slowly than high participation. The drop in participation culture starting in year 8 is caused by the increased hiring. New hires lower average participation experience as rookies need to undergo participation education and coaching from senior people. The surge in hiring during the growth phase from year 9 to 14 dilutes participation culture to below 0.5 units, since medium participation time is not sufficient to keep pace with the workforce expansion. The dilution of participation culture loop B2 in Figure 9.1 dominates the productivity gain loop R2. As a result, the intended productivity gain from participation is canceled out. A firm can either choose to expand its workforce at a slower pace to ensure a sustained high participation culture (a practice some companies, such as W. L. Gore, adopt) or it can increase participation effort so rookies can catch up faster. The key insight for managers is to consciously choose a participation policy that sustains a high participation culture that passes the tipping threshold, so that the productivity gain loop R2 dominates the work effort loss loop B1 and dilution of participation culture loop B2, which leads to higher firm performance.
Proposition 8 (Tipping Threshold of Participation Culture): Participation culture (a stock concept) is accumulated from the past participation effort (a flow concept) and can be diluted with increased workforce.

There is a tipping threshold of participation culture where, before crossing it, productivity decreases due to the learning curve in participation effort. After participation culture passes the threshold, productivity gain from participation outweighs work effort loss from employee education and coaching effort. As a result, firm performance increases.

Low participation effort can make firm performance worse than no participation if there is insufficient participation culture to trigger the productivity gain from participation.

Medium participation effort can have minimal impact on firm performance when productivity gain is washed out by work effort loss. Increased hiring during the growth phase can dilute the participation culture if participation effort does not keep pace with the workforce expansion.

High participation effort can increase firm performance once the firm builds up strong participation culture that causes productivity gain to outweigh work effort loss from employee education and coaching effort.

For participation to work, managers should aim to sustain a high participation culture that passes the tipping threshold, such that the productivity gain loop R2 dominates the work effort loss loop B1 and dilution of participation culture loop B2 in Figure 9.1. Adopting a sustained participation effort independent of work pressure is one way to achieve a high participation culture.
Figure 11.4: Partitioning Policy: No Partitioning (Green), Low Partitioning (Red), and High Partitioning.
11.5 Combination Effects

11.5.1 Participation with Employee Ownership

Policy experiments above show the effect of participation effort alone without any shared capitalism mode of compensation. What is the combination effect of participation and stock grants? Figure 11.15 shows three policy runs. The blue line is the base case without participation or stock grants. The red line is high participation without stock grants. This is the case where productivity increases when participation culture crosses a tipping threshold. The green line is the combination of high participation with annual stock grants worth 10% of industry compensation. Notice that indicators of firm performance (net income, working capital and stock price) are all much higher with the combination of participation and stock grants than with participation alone. This is because stock grants mediate and close the employee ownership loop, R2, which enables the direct effect of participation on productivity to be amplified through the closed reinforcing loop. This can be seen in the green line in the job satisfaction graph, where higher stock price leads to higher job satisfaction and increases productivity even more than participation alone.

The key insight is that participation alone only taps into its direct effect on productivity (Figure 11.16). Participation in combination with employee ownership enables the productivity gain from participation to be reinforced and amplified through the employee ownership loop (Figure 11.17). Participation with employee ownership works better than participation or employee ownership alone. It is important to combine both the “soft” participation management with the “hard” employee ownership financial incentives to make shared capitalism work. Having participation alone only give employees “a sense of lunch,” whereas employee ownership gives people “the actual lunch” (Rosen and Rodgers 2007). This insight has implications for the organizational development field, which focuses primarily on the soft HR practices without taking into consideration the importance of the hard financial incentives. Shared capitalism modes of compensation are effective tools to reinforce and amplify the organizational development change efforts.
Proposition 9 (Combination Effect of Participation and Employee Ownership):

Participation with employee ownership improves job satisfaction and firm performance more than participation or employee ownership alone. This is because participation alone only taps into its direct effect on productivity. Employee ownership closes the employee ownership loop by mediating the financial performance-employee behavior link. As a result, participation in combination with employee ownership enables the productivity gain from participation to be reinforced and amplified through the employee ownership loop.
Figure 11.15: Participation vs. Stock Grants (Red), and Participation with 10% Stock Grants (Green).
Figure 11.16: Causal Loop Diagram of Participation Effect
Figure 11.17: Causal Loop Diagram of Participation with Employee Ownership
11.5.2 Participation with Profit Sharing

What about other combination effects among employee ownership, profit sharing and participation? Figure 11.18 shows the base case without profit sharing or participation (blue), profit sharing as 10% of net income only (red), and profit sharing as 10% of net income with participation (green). Similarly to the findings in the previous section, the combination of profit sharing with participation outperforms profit sharing and participation alone. This is because profit sharing mediates the firm performance-employee behavior link and closes the profit sharing loop R3. The direct effect of participation on productivity is amplified and reinforced through the profit sharing loop. It is worth noting that the reinforcing effect is triggered only when the firm has positive net income, whereas in the employee ownership case, the reinforcing effect is triggered regardless of the profit level.

Proposition 10 (Combination Effect of Participation and Profit Sharing): Profit sharing with participation improves job satisfaction and firm performance more than profit sharing or participation alone. This is because participation alone only taps into its direct effect on productivity. Profit sharing closes the profit sharing loop by mediating the financial performance-employee behavior link. As a result, profit sharing in combination with participation enables the productivity gain from participation to be reinforced and amplified through the profit sharing loop.
Figure 11.18: Profit Sharing vs. Participation Combination Effect: No Profit Sharing and No Participation (Blue), 10% Profit Sharing (Red), and 10% Profit Sharing with Participation (Green).
11.5.3 Participation with Profit Sharing, Stock Options and Stock Grants

Figure 11.19 shows five policy runs: 1) the base case without participation, profit sharing, stock options or stock grants (blue); 2) participation only (red); 3) participation with profit sharing as 10% of net income (green); 4) participation with profit sharing as 10% of net income plus 10 basis points of stock options (grey); and 5) participation with profit sharing as 10% of net income plus 10 basis points of stock options and annual stock grants worth 10% of industry compensation (black). The more shared capitalism practices are combined, the higher the job satisfaction, productivity and firm performance. The productivity graph distinguishes the effects from each additional practice. Productivity increases as more practices are combined. This is because the direct effect of participation on productivity gets amplified and reinforced through two closed profit sharing loops and the employee ownership loop. The two closed loops strengthen the feedback from firm performance to employee behavior and make the loop gain higher than that of individual loops alone. Higher loop gain amplifies any direct effects (such as participation) more than the direct effects alone. Seeing how shared capitalism practices close the firm performance-employee behavior loops helps to explain why combined practices outperform individual ones. Figure 11.20 illustrates the holistic feedback system of shared capitalism practices.

Proposition 11 (Combination Effect of Shared Capitalism Practices): Combinations of shared capitalism practices outperform individual ones alone. The more shared capitalism practices (such as participation, profit sharing and employee ownership) that are combined, the higher the job satisfaction, productivity and firm performance. This is due to the “hard” financial incentives (such as stock options, stock grants and profit sharing) closing the feedback loops from firm performance to employee behavior, thus enabling the “soft” human resource practices (such as participation and training) to amplify their direct effects on firm performance.
Figure 11.19: Participation, Profit Sharing and Stock Grants Combination Effect: Base Case (Blue), Participation only (Red), Participation with 10% Profit Sharing (Green), Participation with 10% Profit Sharing and 10% Stock Options (Grey), and Participation with 10% Profit Sharing, 10 Basis Point Stock Options and 10% Stock Grants (Black).
Figure 11.20: Causal Loop Diagram of Shared Capitalism Policies (Salary, Employee Ownership, Profit Sharing and Participation)
11.6 Salary vs. Stock Grants

The analysis above assumed a fixed salary level while varying the level of stock grants. In practice, the entrepreneur could lower the salary and replace it with stock grants to conserve cash. What combinations of salary and stock grant levels outperform the base 100% salary case with no employee ownership? To answer this question, I ran 1,600 simulations of various combinations. Figure 11.21 on the left shows the market capitalization at year 15 under various combinations of salary and stock grant levels. The horizontal axis shows different levels of salary between 50% and 150% of industry compensation that a manager could adopt. 91.25% means that the firm adopts a policy of paying its employees a below-the-market salary worth a constant 91.25% of industry average. The depth axis shows various levels of stock grant value between 0% and 200% of industry compensation. These two axes denote the various combinations of salary and stock grants a manager could choose as a combined compensation policy. The vertical axis shows the value of market capitalization at year 15 when the manager adopts a certain constant combination of salary and stock grant levels throughout the model run. The line between the red and blue areas is the $300 million base case line. Any point on that line denotes a certain combination of salary and stock grants that renders the same market capitalization as the base case. The area above the base line is the result of policies that outperform the base case.
Figure 11.21 on the right presents a two-dimensional contour diagram of the 3D graph from a bird’s-eye view. The purple area denotes the best-performing market capitalization. The blue area is the market capitalization that underperforms the base case, under the policies of very low salary with little to no stock grants on the left side, or high salary with or without stock grants on the right. The base line is the curve between the red and blue area Every point on the base line is a combination of salary and stock grants that generates the base market capitalization at year 15.

To understand the dynamics that generate Figure 11.21, it is helpful to explain the base line curve. First, Figure 11.22 shows that, as salary decreases, one needs to increase stock grants to maintain the base performance. This is because a low salary lowers financial compensation, job satisfaction, employee productivity and effective work effort (1. lower productivity). The side benefit of low salary is that it enables the firm to hire more people for a given headcount budget driven by the working capital (2. more hiring). However, the increase in hiring is not enough to offset the productivity decrease – effective work
effort is still lower than the base case. To maintain the base case effective work effort, the firm needs to award stock grants that close the employee ownership loop – because the increase in stock grants value increases financial compensation, job satisfaction and productivity to the point that effective work effort restores to the base case value, which generates the base case values of sales, net income and market capitalization (3. EO loop). This demonstrates the scenario where employee ownership can be used as a compensation tool in combination with lower salary in order to conserve cash and expand the workforce.

Figure 11.22: Causal Loop Diagram of Low-Salary, Low-Stock-Grant Strategy
Second, Figure 11.23 shows that, when salary is increased, one needs to combine that with high stock grants in order to maintain the base case market capitalization. This is counter-intuitive — why does one need to award employees high stock grants on top of high salary? The causal diagram explains it. A high salary increases financial compensation, job satisfaction and employee productivity. However, the productivity is increased at a diminishing rate due to the functional form of the effect of financial compensation on job satisfaction (1. limited productivity increase). The unintended consequence of a high salary strategy is that it burns cash faster, thus lowering the number of people hired (2. fewer people). The limited productivity increase is not enough to offset the loss in headcount, and hence the effective work effort is lower than the base case value. To restore effective work effort to the base case value, the firm can increase productivity further by awarding stock grants. However, due to the diminishing return in job satisfaction and productivity, one needs to award a large amount of stock grants to raise productivity enough to restore effective work effort (3. EO Loop).

In short, the intended productivity gain of a high salary strategy can be offset by the diminishing returns in productivity gain and the limited workforce due to expensive headcounts. High salary alone with no employee ownership performs worse than the market average salary alone. It is worth noting that high salary here means a policy of high salary for all employees (e.g., everyone’s salary increases by 30%). The model does not address differential pay raises to a workforce differentiated by functions or performance (Becker, Huselid and Beatty 2009). Further work could disaggregate employees into different performance levels to study the effect of a differentiated salary strategy.
Figure 11.23: Causal Loop Diagram of High-Salary, High-Stock-Grant Strategy
What combinations of salary and stock grants produce a founder’s net worth that outperforms the base case value? Figure 11.24 show the comparable 3D and contour graphs for founder’s net worth. The base line curve of $50 million is the line between the yellow and red areas. The area inside the base line curve is combinations that outperform the base case. The purple area with low stock grants and around market salary produces the best founder’s net worth. The underperforming red and blue areas on the top are caused by the dominance of the dilution effect due to high stock grants.

Figure 11.24: Founder’s Net Worth at Year 15 under Various Salary and Stock Grant Levels

Figure 11.25 presents four types of strategy that can generate the base case value. First, the lower-left quadrant is the “cheap labor” strategy with low salary and low stock grants. A low salary with low stock grants leads to low productivity but more employees. Low stock grants also lead to low founder’s dilution. The founder attains her net worth through a large share of a small pie of market capitalization. Second, the upper-left
quadrant is the “cheap labor with ownership” strategy with a low salary and high stock grants. Low productivity caused by low salary is offset by productivity increase from high stock grants. However, it is done at the cost of high dilution. In this quadrant, the total pie is large but the founder’s share is small. Third, the lower-right quadrant is the “expensive labor” strategy with a high salary and low stock grants. This leads to merely medium productivity due to the diminishing returns in productivity gain. It also leads to fewer people due to expensive headcount. As a result, market capitalization is smaller. The low stock grant also leads to low dilution. The founder attains her net worth through a large share of a smaller pie. Fourth, the upper-right quadrant is the “expensive labor with ownership” strategy with a high salary and high stock grants. This leads to a high productivity gain, but at the cost of fewer people and a higher dilution. This is the case of a smaller share of a larger pie.

Figure 11.25: Four Quadrants of Founder Net Worth
Figure 11.26 show the 3D and contour graphs for employee net worth. The base case of no employee ownership produces $0 employee net worth. The base line is the horizontal axis when stock grant is zero. As stock grant increases, employee ownership increases, which leads to higher employee net worth. Yellow is the maximum employee net worth, driven by low salary (to conserve cash and expand workforce) along with high stock grants (to increase productivity and employee share of the wealth).

Figure 11.26: Employee Net Worth at Year 15 under Various Salary and Stock Grant Levels
Figure 11.27 presents the contour diagrams for market capitalization, founder’s net worth, employee net worth, employee productivity effect and headcount, all at year 15. It shows the two main reinforcing loops, R1 hiring and R2 employee ownership, that explain the contour results.

Market capitalization is split into founder, employee and venture capital net worth (not shown). The employee productivity effect shows productivity increases from the least (in the red lower left-hand corner) to the highest (at the top). The small arrow in each diagram points to the base case line. The low productivity is caused by low salary and low stock grants. As salary and stock grants increase, productivity increases. The highest productivity, at the top, is driven by the best employee net worth. High productivity leads to high market capitalization and employee net worth, which increases productivity even more (R2 Employee Ownership Loop).

The headcount diagram on the right shows the number of employees. The blue is the least headcount area, driven by high salary cost. The purple is the highest headcount, caused by low salary and high stock grants. Higher productivity and headcount lead to higher effective work effort, which drives up net income and market capitalization. High net income and working capital lead to expansion of workforce (R1 Hiring Loop). The hiring loop and the employee ownership loop are the two main loops that generate the dynamic behavior shown in the contour diagrams.
Figure 11.27: Contour Diagrams of Market Capitalization, Founder Net Worth, Employee Net Worth, Employee Productivity and Headcount at Year 15

Employee Net Worth at Year 15
(Base Case = 0 $Million)

Employee Productivity Effect at Year 15
(Base Case = 1 Index)

Number of Employees at Year 15
(Base Case = 140 People)

Founder Net Worth at Year 15
(Base Case = $50 Million)

Market Capitalization at Year 15
(Base Case = $300 Million)

Figure 11.28 shows four types of firm objectives and the corresponding HR strategies.

1. **Best Market Capitalization**: Area 1 shows the maximum market capitalization and employee net worth with the worse founder net worth than the base case. To achieve the objective of maximizing market capitalization, low salary with high stock grants is the strategy. Low salary conserves cash and enables workforce expansion. High stock grants close the employee ownership loop and generate high employee net worth, which leads to high productivity. High productivity along with workforce expansion leads to maximum market capitalization. The hiring loop and the employee ownership loop reinforce each
other into a virtuous cycle and generate the highest market capitalization. However, the founder net worth is worse than in the base case due to excessive dilution.

2. Best Founder Net Worth: Area 2 shows the maximum founder net worth, but mediocre market capitalization in comparison with the base case. To achieve the objective of maximizing founder net worth, market salary with low stock grants is the strategy. Low stock grants weaken the employee ownership loop and result in a mediocre market capitalization that is only slightly better than the base case. Low stock grants also reduce dilution, which enables the founder to capture the wealth. This is the case of a small pie (market capitalization) with a large share (founder ownership). This is optimal for the founder but the total market capitalization is suboptimal. There is a unrealized potential wealth that is missing due to a weak employee ownership loop.

3. Mutual Gain: Area 3 shows the scenario where both founder and employee net worth outperform the base case. To achieve the objective of mutual gain, market salary with medium stock grants is the strategy. Medium stock grants strengthen the employee ownership loop without overly diluting the ownership. The productivity gain from employee ownership outweighs the dilution effect. Making stock grants increases both founder and employee net worth, as long as it is within the tipping threshold.

4. Lose-Lose: Area 4 shows the worst-performing market capitalization and founder net worth. To prevent lose-lose for the company and founder, very low or high salary with no stock grants is the strategy to avoid. With no stock grants, there is no employee ownership loop and the potential productivity gain is untapped. Varying salary too much without stock grants underperforms because its intended effect can be washed out by unintended consequences. For example, low salary enables hiring more employees. However, too low salary lowers productivity and net income, which shrinks the headcount budget, which results in fewer employees. Fewer employees lead to low work effort and net income. The hiring loop turns into a vicious cycle. On the other hand, very high salary increases productivity by only a limited amount, due to diminishing returns. It also reduces the headcount as employees become more expensive. In sum, too low or too high salary without stock grants underperforms.
Figure 11.28: Firm Objective and HR Strategy

Employee Net Worth at Year 15
(Base Case = 0 $Million)

Employee Productivity Effect at Year 15
(Base Case = 1 Index)

Number of Employees at Year 15
(Base Case = 140 People)

Founder Net Worth at Year 15
(Base Case = $50 Million)

Market Capitalization at Year 15
(Base Case = $300 Million)

Objective	Strategy
1	Best MC, EW: S + G
2	Best FW: Mediocre MC
3	Mutual Gain: S + G
4	Lose-Lose: S + G

Salary: Low, Mediocre, High
Stock Grants: Low, Mediocre, High

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11.7 Main Insights

The main insights of the policy analysis are:

1. Employee ownership creates, and mediates the strength of, the reinforcing feedback loops from firm performance to employee behavior.
2. Salary has a direct effect on productivity and hiring but does not close the firm performance to employee behavior feedback loop.
3. Stock grants have productivity gain, diminishing returns and dilution effects.
4. The impact of salary and stock grants on firm performance is sensitive to the non-linear effect of total compensation on job satisfaction.
5. The impact of shared capitalism policy on firm performance depends on the dynamic tradeoffs among the four effects: hiring, productivity gain, diminishing returns and dilution.
6. The more wealth is shared through broad-based employee ownership, the more wealth is created, given the appropriate conditions.
7. To attain mutual gains for founder and employees, a policy of market average salary, plus sufficient stock grants to strengthen the employee ownership loop without overly diluting the ownership, is recommended.
12. SENSITIVITY ANALYSIS

This chapter shows two sets of sensitivity analysis. Section 12.1 shows a sensitivity analysis of the effect of financial compensation on job satisfaction. Section 12.2 presents a sensitivity analysis of a sudden decrease in sales productivity.

12.1 Effect of Financial Compensation on Job Satisfaction

The impact of shared capitalism policy depends on the strength of the employee ownership loop. The strength of that loop in turn depends on the functional form of the effect of financial compensation on job satisfaction. To test how sensitive the analysis is to the functional form, I ran the same 1,600 simulations using the function forms at the lower and upper bounds of the 95% confidence interval (reprinted below).

Figure 8.2c: 95% Confidence Interval of the Effect of Financial Compensation as % of Industry Average on Job Satisfaction
Figure 12.1 shows the sensitivity analysis of the effect of financial compensation on job satisfaction. It presents market capitalization at year 15 when the financial compensation effect is at the lower and upper bounds of the 95% confidence interval. In the lower bound scenario, the base case line between red and blue areas is shifted to the left. This is because the maximum financial compensation effect on job satisfaction is capped at 130%. When the combined value of salary and stock grants passes 130% of the industry compensation, job satisfaction reaches its peak and, as a result, there is no additional productivity gain. Increasing stock grants beyond the 130% mark does not increase firm performance. The productivity gain from the employee ownership loop is weakened. The blue area is larger than the center bound case—more combinations of salary and stock grants underperform the base case. In fact, the likelihood of bankruptcy increases—the area to the right and below the black line signifies zero market capitalization at year 15. The 3D graph on the left in Figure 12.2 shows this clearly.

The upper bound scenario shows the opposite result. There are more combinations of salary and stock grants that outperform the base case, and the outperformance is at higher magnitudes. Shared capitalism policy creates higher market capitalization because the productivity gain in the employee ownership loop is strengthened in the upper bound scenario. This is due to the upward-shifting red line in Figure 8.2c, which increases the effect of additional salary and stock grants on job satisfaction and productivity.
Figure 12.1: Sensitivity Analysis of the Effect of Financial Compensation on Job Satisfaction (Market Capitalization in Contour Diagram).

Figure 12.2: Sensitivity Analysis of the Effect of Financial Compensation on Job Satisfaction (Market Capitalization in 3D Graph)
The sensitivity results for founder net worth show a similar pattern (Figure 12.3). The number of outperforming combinations of salary and stock grants (yellow area) shrinks in the lower bound scenario due to the weakened employee ownership loop. It expands in the upper bound case as the loop strengthens. This sensitivity analysis shows that although the magnitude of the shared capitalism policy effect could be weakened or strengthened, its directional effect within the 95% confidence interval stays the same. The main policy insights stated in Section 11.7 remain intact.

Figure 12.3: Sensitivity Analysis of the Effect of Financial Compensation on Job Satisfaction (Founder Net Worth)
12.2 Decrease in Sales Productivity

The analysis so far assumes there is one startup firm and one incumbent with no new entrants into the market. To test the sensitivity of the model results under competitive pressure, I ran simulations with a step decrease of sales productivity at year 6 onwards till year 15. Since new entrants offering competing products are likely to lower the firm’s sales productivity, this shock signifies the uncertainty in market competition.

Figure 12.4 shows the sensitivity results. The horizontal axis denotes the size of shock from 0 to 50% of sales productivity decrease from year 6 onwards. The vertical axis is the market capitalization at year 15. Two HR policies are compared. The blue is the case of 100% salary with no stock grants. The red is 80% salary plus 14% stock grants. Both policies give the same base case market capitalization when there is no shock – this gives us the equal starting point for comparison.

As expected, the larger the shock (signifying higher competition), the lower is the market capitalization. There is a tipping point where the shock is too large (around 30%), so that the firm goes bankrupt, as there is not enough sales generated to sustain the firm. The firm is outcompeted and has ceased to exist by year 15.

The red line declines more steeply than the blue one for a given shock, i.e., the same shock reduces market capitalization more for the lower salary with stock grant policy than for the market salary case. This is due to the positive feedback loop of employee ownership working in the vicious direction. A shock of low sales productivity leads to lower sales and net income, which leads to lower stock price and stock grants value. This in turn reduces job satisfaction and employee productivity more than in the 100% salary case. Thus, employee ownership creates the reinforcing loop connecting firm performance and employee behavior. However, the virtuous or vicious direction of the loop depends on other factors, such as competitive pressure. Being an employee ownership company does not guarantee success; sound business strategy is needed to fend off competitors. This sensitivity analysis shows that, in a downturn, the employee
ownership loop could work in a vicious direction and cause the firm to underperform the 100% salary case.

Figure 12.4: Sensitivity Analysis of Decreases in Sales Productivity
13. CLEAN TECHNOLOGY STARTUP MANAGEMENT FLIGHT SIMULATOR

This chapter describes the Clean Technology Startup Management Flight Simulator, a computer simulation game developed for teaching the dynamic strategies of running a clean technology startup company. It is based on the model presented in this thesis and aims to make the insights from this research experiential through an interactive learning environment. The game interface is developed using Venapp software where students can play the game with a user friendly dashboard and timely reports. A teaching assignment is developed to enhance the real time learning experience.

13.1 Learning Objectives

The intended audiences for the simulator are students in human resource management, employee ownership, entrepreneurship, sustainability and strategic management. There are four learning objectives:

1. **Systems approach**: learning to see employee ownership management as an important part of the larger corporate system where it is interconnected with human resource management, product development, sales and financing strategies.
2. **Dynamic effects**: learning about the dynamic effects of employee ownership management overtime through broad-based stock grants, stock options and profit sharing schemes.
3. **Experiential learning**: through a real-time simulation game, students learn under what conditions various employee ownership management strategies improve employee well-being and firm performance overtime.
4. **Clean technology startup**: the simulation game is based on the scenario of a clean technology startup company. Students learn about the business and human resource strategies of growing and managing a clean technology company.
13.2 Simulator Overview

Below is the cover screen of the simulator.

![Simulator Cover Screen](image-url)
After clicking “Enter”, the main menu is shown below.

![Main Menu]

By clicking “Simulator Overview,” the simulator provides the following introduction.
Your Challenge

Your startup firm and product

You are the founder, president and CEO of a clean technology startup company. For concreteness, imagine that your firm has developed a set of technologies to improve energy efficiency for your customers (for example, the owners and operators of commercial and industrial buildings), cutting their energy costs while lowering their carbon footprint. You’ve developed a set of sensors, controls, and software that work seamlessly to optimize the efficiency of the HVAC, lighting and other systems in commercial and industrial facilities. As the simulation starts, your product offers what you consider to be a highly attractive value proposition for building owners – your target customers. You estimate that the average customer can reduce their current energy use by 30% if they buy your system. The unit cost of your product is initially $100,000. If you charge $120,000 (a 20% margin to cover your indirect costs and provide an acceptable return on capital), with an annual service fee of 10% of the product price, you estimate that the simple payback period for your customers is two years, even at current energy prices. That is, your product pays for itself in just two years.

Market

Based on these savings and the prospect for further improvements as you develop your technology, you foresee a substantial potential market for your product. However, given that this is a new product unfamiliar to many customers, it takes roughly one year for a customer to go from learning about the product to the decision to purchase the product. The size of the potential market and the likelihood of closing a sale depends on how attractive your product is, as perceived by the potential customers. The attractiveness of your product depends of course on the financial benefits it offers the customer (measured by the payback time or NPV of the savings you offer them), but also depends on your ability to provide high quality service and support. As with any new product and new company, potential customers feel more comfortable and are more likely to adopt if other firms have also done so, so word of mouth from other adopters is important in the decision of potential customers to consider and ultimately adopt your product (entrepreneurs know that one of the first questions they will hear from potential customers early on is “Who else is using your product?”). Because your product is expensive and requires significant changes in the way your customers operate their buildings, sales do not occur on the basis of word of mouth or advertising alone, but require sustained direct sales effort. The more time your sales team can devote to that process, and the more skilled and motivated they are, the more customers you move through the sales cycle.
Product Development

While you believe your initial product offers a good value proposition for potential customers, it can be improved as technology develops and as you learn from the experience and suggestions of your customers. And you need to improve at as your competitors (such as the incumbent utilities that currently provide energy to buildings). Your engineering team develops and improves the product. However, your engineers are also needed to provide support and service to existing customers. The larger the installed base of your product, the more customer service effort is needed, drawing time away from product development. The larger your engineering team, and the more skilled and motivated they are, the better the quality of service they can provide to existing customers and the faster they can improve the product.

Revenue and Costs

Your revenue comes from sales of your product and the annual customer service fee for system maintenance and upgrades. Your main costs are the expenses associated with your employees (sales people and engineers), primarily salary but also the cost of providing the space, equipment, etc. they need to be effective, and the cost of goods sold.
You begin with initial cash on hand of $1 million representing capital you raised from angels during the initial development phase. Your job is to grow the company, survive the ‘valley of death’ without running out of cash, and maximize the firm valuation, your net worth and cumulative profit over a period of ten years (you decide whether you want to focus on your net worth, on building the best company you can, and whether these goals are aligned or not). You do so by making four sets of decisions each quarter. Those decisions involve pricing, headcount, financing and compensation.

You will receive quarterly reports including information on sales, the income statement, cash flow, shares outstanding, product attractiveness, and human resources in the report panel. You should select your strategies based on those reports, your understanding of the underlying industry structure, and your best judgment about how your employees and customers may respond.

Will you crash and burn or become the next millionaire while saving the planet?
13.3 Scenario Settings

Below is the scenario settings screen where the students can change various conditions in product development, market, finance and energy and carbon price. This allows the students to test different strategies under various industry conditions. Average Feature Development Time captures the length of product development cycle from short (such as a software company) to long period (such as clean technology or biotechnology). Initial Feature Relative to Incumbent sets how competitive the startup’s product offering is at the beginning. Sales Cycle Time sets the time it takes to move a typical potential customer through the prospect chain to become an adopter. Potential Market Size allows one to test strategies under different market sizes. VC Investment Climate determines how easy or difficult it is to attract VC financing, given the same product attractiveness. It simulates the macroeconomic environment. Energy and Carbon Price allows one to test different scenarios of energy policy.
13.4 Model Dashboard

Below is the model dashboard where the game decisions are entered on the left hand column. Students can input their decisions on pricing, headcount growth rate, engineer proportion, VC financing amount, IPO date, salary, stock options, stock grants and profit sharing percentage every quarter. Each decision variable is described in Section 13.6. An overview of the key variables in the model is exhibited on the right. There are also a set of detailed reports in the bottom-right hand corner.

13.5 Reports

There are eight detail reports where the students can study in depth to sense-make the underlying causal mechanism that generates the patterns of behavior shown in the reports. This process aims to train students the systems thinking capability for running a startup company.
13.5.1 Sales

Below shows the total addressable market size (which increases as the product becomes more attractive), the prospect sales in the customer chain, quarterly sales and accumulated sales.
13.5.2 Product Attractiveness

Below shows the drivers of product attractiveness such as the customer payback period, customer service quality, price and energy cost savings. The lower the price and the higher the energy cost savings, the lower the customer payback period.
13.5.3 Income Statement

A detailed income statement with key graphs is shown below.

<table>
<thead>
<tr>
<th>Year: 7</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue from Sales</td>
<td>$(Q_{\text{Quarter}})$ 11.43 M</td>
</tr>
<tr>
<td>Revenue from Service</td>
<td>566,113</td>
</tr>
<tr>
<td>Cost of Goods Sold</td>
<td>8,667 M</td>
</tr>
<tr>
<td>Gross Profit</td>
<td>3,433 M</td>
</tr>
<tr>
<td>Salary Expense</td>
<td>694,910</td>
</tr>
<tr>
<td>General &amp; Administrative</td>
<td>356,763</td>
</tr>
<tr>
<td>Operating Income Tax</td>
<td>2,508 M</td>
</tr>
<tr>
<td>Net Income</td>
<td>2,240 M</td>
</tr>
<tr>
<td>Cumulative Profit ($)</td>
<td>-66a,200</td>
</tr>
<tr>
<td>NPV of Profit ($)</td>
<td>-1,222 M</td>
</tr>
<tr>
<td>Date of First Profit (Year)</td>
<td>5</td>
</tr>
<tr>
<td>Startup Losses ($)</td>
<td>-4,893 M</td>
</tr>
<tr>
<td>Cumulative Losses ($)</td>
<td>-4,893 M</td>
</tr>
<tr>
<td>Price ($/Unit)</td>
<td>70,000</td>
</tr>
<tr>
<td>Unit Direct Cost ($/Unit)</td>
<td>61,234</td>
</tr>
<tr>
<td>Gross Margin (Fraction of Revenue)</td>
<td>0.29</td>
</tr>
<tr>
<td>Return on Sales</td>
<td>0.18</td>
</tr>
<tr>
<td>Quarterly Purchases (Units/Quarter)</td>
<td>163</td>
</tr>
</tbody>
</table>

Quarterly Revenue (Sales & Service)

Quarterly Gross Profit & Operating Expense

Quarterly Net Income

Cumulative Profit
13.5.4 Cash Flow

Below presents key cash flow indicators: cash, runway, cash flow from operations and cash flow from financing. For example, there are two injections of venture capital financing at year 1 and 3. The runway becomes zero when there is positive cash flow because the firm is no longer burning cash.
13.5.5 Shares Outstanding and Ownership Structure

Below shows firm valuation, stock price and strike price. It also shows the shares outstanding, ownership percentage and net worth for founders, venture capitalists, employees and public (if there is an IPO). This allows students to analyze how much total wealth is created and distributed.
13.5.6 Human Resources

Below presents key human resource indicators such as job satisfaction, turnover, number of sales versus engineers, employee quality, average workweek and employee experience. It gives students a glimpse of how various compensation strategies influence employee behavior.
13.5.7 Managerial Decisions

Below records a set of decisions students make in the game. It gives an overview of the employed strategy for later reflection.
13.5.8 Compare Runs

One could run the game multiple times and save each game under different run number. The compare runs function enables students to compare multiple runs at once. One can select many key variables shown on the right below and analyze what causes the difference in performance. A comparison of net income from two runs is shown below.

13.6 Teaching Assignment

The Clean Technology Startup Simulator has been used in the Sustainability Lab at MIT Sloan School of Management. Below presents a set of questions one can use in a teaching assignment.
Assignment Questions

You will make four sets of decisions (pricing, headcount, financing and compensation) in the simulation. To facilitate learning in a complex environment, we will start with a small set of decisions and understand their effects before expanding to others. Please follow the sequence to maximize your learning.

Stage I: Pricing and Headcount

This stage focuses on your pricing, HR growth and product development vs. sales strategies. You are to made three decisions only:

Pricing ($/unit): What price would you set for your product? The initial unit cost is $100,000. Higher price provides a higher margin and more resources you can invest in building your sales and engineering capabilities, but also lengthens the payback period for customers, lowering the attractiveness of your product for customers. Lower price may increase sales effectiveness but at a lower profit margin. Pricing lower than unit cost incurs profit losses. Unit cost goes down over time due to learning from experience, from customers, and from engineering effort to improve the product. You believe unit costs might fall about 2.5% every time your cumulative experience (aggregating learning by doing and engineering effort) doubles.

Headcount Growth Rate (%/Quarter): How fast do you want to grow the total number of employees? 100% means you target a doubling of your workforce in a quarter, -50% means trimming your staff by half. What is your headcount growth strategy to generate revenue growth while not running out of cash?

Engineer Proportion (%): What proportion of your total headcount growth is allocated to engineers as opposed to sales people? Engineers perform customer service and product development, while sales people bring in customers and revenue. You need not only a good product but also customers who know your product and are willing to buy it. What is your product development and sales strategy?

What you should do:

**Stage I: Growth and Pricing**

1. *Before* playing each game, note down your strategy and briefly explain your reasoning. A strategy is a decision rule, not a set of decisions. For example, "grow the engineering staff quickly to improve product functionality, then begin to hire sales people once our offer is sufficiently attractive so that sales effort will be successful" is a strategy; "grow the staff at 40%/year with 70% engineers for the first year, then 70% sales people for year 2" is not a strategy but a set of decisions.
2. Now play the game working only with the three decisions above (pricing, headcount growth, allocation between engineering and sales). Are you able to escape the valley of death? Note down what happens and why when you go bankrupt (if you do).

3. Briefly describe the best strategy you found. What is your pricing, HR growth and product development vs. sales strategy? How is it different from your initial strategy? You can copy and paste your decisions into your writeup by clicking “Decisions” in the dashboard and then copying. To compare runs, you can save runs as Run 1 to 5 in the dashboard, and compare them by pressing “Compare Run.”

4. Why did your best strategy work or not work? What, if any, insights into the dynamics of clean technology startups did you gain from this stage of the game?

**Stage II: Financing**

In addition to the three decisions in Stage I, you are to make two additional decisions regarding your external financing strategy.

**VC Financing ($):** You can raise external capital in the venture capital market. How much VC financing do you want, and how much equity will it cost you? The lower the value of the firm, the higher the ownership stake the VCs will require to provide a given amount of financing. And, if the VC’s due diligence suggests that your firm is not viable or too risky, they will not provide the financing you need. To win VC funding, select the amount you want and run the model for a quarter. If the VCs find your firm attractive (based on the attractiveness of your product, their estimate of the size of your market, etc.), you may receive all or part of the funding you sought. The fraction of ownership you had to pay the VCs will be displayed. You may choose to apply for multiple rounds of VC funding. Doing so however may significantly dilute your ownership.

**IPO Date:** You may also consider trying an IPO. Select the year that you would like to take your company public. If successful, you can use the funds from the IPO to expand your company, and you (and/or your employees and VC partners) may become millionaires. The extent of your ownership dilution depends on the firm valuation at the time of the IPO.

5. *Before* playing the game, note down your financing strategy and briefly explain your reasoning.

* How many times should you play? That is up to you. You should not need to spend more than a few hours on the assignment. To maximize your learning, you should follow the principles of scientific method: formulate (and write down) your hypothesis (strategy) before each game you play; evaluate your strategy and hypotheses about the causal structures driving the dynamics after each game, and test them through controlled experimentation (vary decisions one at a time until you understand each one). You will also learn more playing a lot of games relatively quickly than one game very slowly.
6. Play the game, experimenting with VC financing and, if you believe you can succeed, with an IPO. How does the timing and amount of VC funding influence the firm valuation, your net worth and cumulative profit? You can paste a copy of the financing results by clicking “Shares Outstanding” in the dashboard.

**Stage III: Compensation**

Adding to the right pricing, headcount and financing strategies, startup founders must also design an organization and compensation system that attracts, motivates and retains high quality employees. In this stage, you make four additional decisions regarding employee compensation and the ownership structure for your firm.

**Salary as % of Industry Compensation:** What salary do you offer relative to the industry average for people with the skills you need? Offering salaries above the industry norm will help attract better quality applicants, shorten the time required to fill vacancies, lower turnover, and motivate people to work harder, but it burns cash faster.

**Options Granted per Employee:** You can also attract talent by offering stock options to employees. How many options do you give to each employee per year? The decision here is measured in basis points of total shares outstanding per employee per year. There are initially 1 million shares outstanding in total, so if you give options equal to 1 basis point of total shares per person that means you give options for 100 shares. When the company is doing well and the options are in the money, options help attract better quality applicants for your positions, shorten the time required to fill vacancies, reduce employee turnover, and motivate people to work harder, all while conserving cash resources. However, options don’t vest immediately, and may have no value if the company does not do well and the options are underwater.

**Stock Grants as % of Industry Compensation:** You can also compensate people by giving them an ownership stake in your company. You set the amount to grant each employee per year as a percentage of industry average compensation. For example, the industry compensation is $75,000 per person per year. If you would like to give stock grants worth of 10% of industry compensation ($7,500 per person per year), and the stock price is $10 per share, each employee would receive 750 shares per year. Stock grants help conserve cash, make it easier to recruit employees, reduce turnover, and motivate people to work harder. However, granting stock to employees dilutes your ownership.

**Profit Sharing as % of Net Income:** What percentage of net income do you want to share with the employees as additional compensation? The higher the profit sharing (assuming you are profitable), the more motivated the employees, but the lower the returns to shareholders.
7. *Before* playing the game, note down your strategy to utilize the four compensation options and briefly explain your reasoning.

8. Can you improve on your best strategy to date through the use of different compensation structures? Briefly describe the best strategy you found. How do salary, stock ownership, options and profit sharing influence firm success, valuation, your net worth, and the net worth of your employees?

9. What have you learned, if any, about the chances for success for your firm, for you, for your shareholders, and for your employees from the use of internal financing in compared to the external financing options you explored earlier?

10. What strange behavior or unrealistic assumptions or behavior did you discover in the game? What suggestions for improvements or enhancements do you have? Since this is a beta-version, please report any bugs and suggestions for improvement. For software glitches, please specify the type of machine you used and the version of the Windows you have.
PART V: CONCLUSION

14. SUMMARY OF RESEARCH

This chapter presents a summary of research, a list of propositions and main insights.

14.1 Research Question

Shared capitalism is a diverse set of compensation practices through which worker pay, or wealth, depends on the performance of the firm or work group; compensation practices include employee ownership, stock options, and profit sharing. Empirical studies on whether employee ownership improves firm performance offer mixed results. Kaarsemaker (2006), in a 30-year review of the literature, documented that “two-thirds of 129 studies on employee ownership and its consequences found favorable effects relating to employee ownership, while one-tenth found negative effects. However, favorable effects do not appear to come about automatically, and the specific conditions under which they do are largely unknown.”

This dissertation attempts to address the question: under what conditions do shared capitalism policies improve firm performance? A system dynamics model of high performance work systems estimated using the NBER Shared Capitalism dataset and calibrated to a clean technology startup company is presented. The model provides an explicit causal mechanism of how various shared capitalism policies and HR practices influence employee behaviors which drive business processes, and how those business processes interact with market conditions to generate firm performance in a dynamic feedback system.

14.2 Literature Gap

After conducting a thorough literature review in the field of employee ownership and SHRM/HPWS, four main literature gaps and potential contributions were identified.
14.2.1 Contingency Theory

The specific conditions under which employee ownership yields favorable effects are largely unknown. A contingency theory, as opposed to a universal approach, is needed to answer under what conditions employee ownership improves firm performance.

14.2.2 Causal Mechanisms

The theory of the underlying causal mechanisms of employee ownership effects is underdeveloped. One needs to build a model that captures the causal mechanisms between HRM practices and firm performance.

14.2.3 Systems Approach

The relationships of employee ownership with other HRM practices and several contingencies are too “complex and intertwined” (Poole and Jenkins 1990) to assume a simple isolated relationship with participation in decision-making or some other single factor or number of factors. One needs an integrated systems approach that connects the isolated linkages as a whole.

14.2.4 Dynamic Analysis

Most of the empirical studies on employee ownership effects are static in the sense that they do not take timing into consideration. The field of employee ownership would benefit from a dynamic analysis of how different timing (span across the industry lifecycle) of employee ownership policies affects employee behavior and firm performance over time.

14.3 Method

While most of the empirical studies focus on estimating the relationship between some forms of shared capitalism and firm performance through survey data and regression
analysis, I take a system dynamics simulation approach that is quite different from those present in the existing literature. By explicitly modeling the causal paths from HR practices to performance through various mediating and moderating variables, and simulating the dynamic behavior of performance under various HPWS scenarios, one is able to generate and test a set of causal theories explaining the impact of HPWS on performance.

My approach involves three main steps, using mixed survey data, case study and simulation methods.

1. **Model Building**: I build a system dynamics model of HPWS estimated using the NBER Shared Capitalism dataset and calibrated to a clean technology startup company. The model provides an explicit causal mechanism to show how various shared capitalism policies and HR practices influence employee behaviors that drive business processes, and how those business processes interact with market conditions to generate firm performance in a dynamic feedback system. This model is built on Miller’s (2007) model of clean technology startup companies. My contribution is to add a detailed HPWS with various shared capitalism policies such as salary, stock grants, stock options, profit sharing and employee participation. To build the HPWS structure, I performed a thorough literature review on the existing theoretical and empirical findings of employee ownership and Strategic Human Resource Management (SHRM), and formally modeled them in a system dynamics framework.

2. **Model Estimation and Calibration**: Since employee ownership effects are the main focus of this study, I have estimated the non-linear functional forms of various employee ownership effects by regression analysis using the NBER Shared Capitalism dataset (Kruse, Freeman and Blasi 2010). To calibrate this model, I conducted interviews and collected archival data of an early-stage clean technology startup company. Given the inherent limitation of an early-stage startup when there are no later-stage time-series data, company data was used to parameterize the initial conditions of the model. I interviewed the executives to identify their decision-making rules for pricing, financing, human resource and compensation policies and their projections for business performance. The
base run of the model represents closely the executives’ expectations and confirms the
general patterns of typical startup companies.

There are three reasons why I focus on a startup company. First, shared capitalism
policies such as stock options, stock grants and profit sharing are important motivational
tools in addition to salary in cash-constrained startup companies (Blasi, Kruse and
Bernstein 2003). Second, I am interested in studying the long-term dynamic effects of
shared capitalism policies across the firm life cycle, starting from the founding stage.
Third, research has shown that founders have long-term imprinting effects on
organizational design and policies (Burton 2001, Burton and Beckman 2007, Beckman
and Burton 2008). Understanding the impact of various shared capitalism policies since
the founding phase is highly relevant to the practice of entrepreneurship.

3. Policy Analysis: I conduct simulation analyses to study how various combinations of
salary, stock options, stock grants, profit sharing schemes and employee participation
efforts influence employee behavior and firm performance over time. The simulation
results offer insights into the dynamic effects of shared capitalism policies. Eleven
propositions on the conditions under which shared capitalism policies improve firm
performance are presented. Sensitivity analysis is conducted to ensure the robustness of
the analyses and guide future research.

14.4 List of Propositions

Below is a list of propositions from the policy analysis in Chapter 11. A key causal loop
diagram of shared capitalism policies where these propositions are based on is reprinted
below (Figure 11.20).

14.4.1 Stock Grants

Proposition 1 (Productivity Gain of Employee Ownership): Employee ownership closes
the reinforcing feedback loop from firm performance to employee behavior and generates
additional productivity gain. Given appropriate conditions, higher stock price increases
employees’ stock value, driving up job satisfaction, attracting better employee quality and
reducing turnover. These, in turn, create additional productivity gain, which increases net income and stock price further. At the same time, higher net income enables hiring more workforce, which increases work effort, revenue and net income further. Thus, more wealth is shared through broad-based employee ownership; and more wealth is created, given the appropriate conditions.

**Proposition 2 (Diminishing Returns of Employee Ownership):** There is a diminishing returns of employee ownership effect. The effect of additional employee ownership stake increases job satisfaction, employee productivity, and firm performance at a diminishing rate.

**Proposition 3 (Dilution Effect of Employee Ownership):** Employee ownership has two effects on stock price: productivity gain and dilution effects. First, it creates additional productivity gain and increases stock price by closing the employee ownership loop. Second, it dilutes ownership by increasing total shares, which lowers stock price and founder’s net worth. The two combined effects determine the change in stock price. When too much ownership is granted (past a certain threshold), the dilution effect can outweigh the productivity gain, thereby lowering the stock price and the founder’s net worth.

### 14.4.2 Stock Options

**Proposition 4 (Timing Effect of Employee Ownership):** Stock granted at the cash-negative pre-growth period closes the employee ownership loop early on and enables the firm to capitalize on productivity gains in the early stage and to amplify them in the later period, thereby producing higher net income and market capitalization than the stock granted at the cash-positive growth period. However, higher dilution occurs with the pre-growth-period grants, as more shares need to be issued, given the low firm valuation at the pre-growth stage, which depresses stock price at the later period. The extent of pre-growth versus growth-period grants’ impact on stock price and the founder’s net worth depends on the dynamic tradeoff between productivity gains and the extent of dilution overtime.

### 14.4.3 Profit Sharing

**Proposition 6 (Benefits of Profit Sharing):** An increase in profit sharing as a percentage of net income before a certain tipping threshold increases job satisfaction, productivity, net income, market capitalization, stock price and founder’s net worth at a diminishing rate. Profit sharing causes productivity to increase through higher job satisfaction, better employee quality, and longer work experience from lower turnover.
**Proposition 7 (Tipping Threshold of Profit Sharing):** Once the profit sharing percentage surpasses the tipping threshold, the reduction in net income after expensing profit sharing limits the resources available to expand the workforce. The workforce reduction outweighs the productivity gain from profit sharing, and profit sharing’s influence on work effort and firm performance turns from positive to negative.

14.4.4 Participation

**Proposition 8 (Tipping Threshold of Participation Culture):** Participation culture (a stock concept) is accumulated from the past participation effort (a flow concept) and can be diluted with increased workforce.

There is a tipping threshold of participation culture where, before crossing it, productivity decreases due to the learning curve in participation effort. After participation culture passes the threshold, productivity gain from participation outweighs work effort loss from employee education and coaching effort. As a result, firm performance increases.

Low participation effort can make firm performance worse than no participation if there is insufficient participation culture to trigger the productivity gain from participation.

Medium participation effort can have minimal impact on firm performance when productivity gain is washed out by work effort loss. Increased hiring during the growth phase can dilute the participation culture if participation effort does not keep pace with the workforce expansion.

High participation effort can increase firm performance once the firm builds up strong participation culture that causes productivity gain to outweigh work effort loss from employee education and coaching effort.

For participation to work, managers should aim to sustain a high participation culture that passes the tipping threshold, such that the productivity gain loop R2 dominates the work effort loss loop B1 and dilution of participation culture loop B2 in Figure 9.1. Adopting a sustained participation effort independent of work pressure is one way to achieve a high participation culture.

14.4.5 Combination Effects

**Proposition 9 (Combination Effect of Participation and Employee Ownership):** Participation with employee ownership improves job satisfaction and firm performance more than participation or employee ownership alone. This is because participation alone only taps into its direct effect on productivity. Employee ownership closes the
employee ownership loop by mediating the financial performance-employee behavior link. As a result, participation in combination with employee ownership enables the productivity gain from participation to be reinforced and amplified through the employee ownership loop.

**Proposition 10 (Combination Effect of Participation and Profit Sharing):** Profit sharing with participation improves job satisfaction and firm performance more than profit sharing or participation alone. This is because participation alone only taps into its direct effect on productivity. Profit sharing closes the profit sharing loop by mediating the financial performance-employee behavior link. As a result, profit sharing in combination with participation enables the productivity gain from participation to be reinforced and amplified through the profit sharing loop.

**Proposition 11 (Combination Effect of Shared Capitalism Practices):** Combinations of shared capitalism practices outperform individual ones alone. The more shared capitalism practices (such as participation, profit sharing and employee ownership) that are combined, the higher the job satisfaction, productivity and firm performance. This is due to the "hard" financial incentives (such as stock options, stock grants and profit sharing) closing the feedback loops from firm performance to employee behavior, thus enabling the "soft" human resource practices (such as participation and training) to amplify their direct effects on firm performance.
Figure 11.20: Causal Loop Diagram of Shared Capitalism Policies (Salary, Employee Ownership, Profit Sharing and Participation) (Reprinted)
14.5 Main Insights

The main insights of the policy analysis are:

1. Employee ownership creates, and mediates the strength of, the reinforcing feedback loops from firm performance to employee behavior.
2. Salary has a direct effect on productivity and hiring but does not close the firm performance to employee behavior feedback loop.
3. Stock grants have productivity gain, diminishing returns and dilution effects.
4. The impact of salary and stock grants on firm performance is sensitive to the non-linear effect of total compensation on job satisfaction.
5. The impact of shared capitalism policy on firm performance depends on the dynamic tradeoffs among the four effects: hiring, productivity gain, diminishing returns and dilution.
6. The more wealth is shared through broad-based employee ownership, the more wealth is created, given the appropriate conditions.
7. To attain mutual gains for founder and employees, a policy of market average salary, plus sufficient stock grants to strengthen the employee ownership loop without overly diluting the ownership, is recommended.
15. CONTRIBUTIONS

This chapter presents four types of contributions from this dissertation: theoretical, empirical, methodological and teaching contributions.

15.1 Theoretical Contribution

There are four main points under theoretical contribution.

15.1.1 Systems Approach

This dissertation offers a systems approach to the study of HPWS, employee behavior and firm performance. First, a generic process theory of the firm and the role of managers is presented in Figure 3.1. The four internal processes are employee behaviors, business processes, market conditions and financial performance. The contribution of this framework is its transformation of the traditional balanced scorecard into a dynamic feedback framework with explicit causal linkages connecting across the four quadrants. It can be used to provide a high-level systems view of the firm structure and guide strategic planning for a startup company.
Second, I offer an integrated and comprehensive model of HPWS that incorporates both “hard” financial compensation policies, “soft” HR practices, and their inter-linkages with the whole corporate system. It enables one to view employee ownership management as an important part of the larger corporate system where it is interconnected with human resource management, product development, sales and financing strategies.

15.1.2 Causal Mechanisms

This dissertation helps open the “black box” of SHRM/HPWS by providing explicit causal mechanisms for how various shared capitalism policies and HR practices influence employee behaviors which drive business processes, and how those business processes interact with market conditions to generate firm performance in a dynamic feedback system. A causal loop diagram of HPWS is reprinted below. By making the causal paths
of HR policies explicit, one is able to trace and analyze the cause and effect of each policy and identify high leverage points for managers to intervene.

**Figure 6.4: Causal Loop Diagram of High Performance Work System (Reprinted)**

![Causal Loop Diagram](image)

**15.1.3 Direct vs. Mediating Effects**

One critical insight is that employee ownership and profit sharing are mediating effects that close the reinforcing feedback loops from firm performance to employee behavior. Salary and participation are direct effects that influence job satisfaction and productivity but do not close the firm performance-employee behavior loop. Employee ownership
along with participation effort improves firm performance significantly because closing the firm performance-employee behavior loop amplifies the direct effects of salary and participation. Thus, the more wealth is shared through broad-based employee ownership, the more wealth is created, given the appropriate conditions.

15.1.4 Dynamic Theory

This dissertation offers a dynamic theory of how shared capitalism modes of compensation influence employee behavior and firm performance. In particular, the concepts of tipping thresholds for salary, employee ownership, profit sharing and participation culture are proposed in propositions 3, 7 and 8.

15.2 Empirical Contributions

In addition to theoretical contributions, this dissertation also offers some empirical contributions. The six table functions estimated using the large NBER Shared Capitalism dataset provide rigorous empirical estimations of the so-called “soft” variables on employee behavior such as effect of employee ownership on job satisfaction, effect of profit sharing on job satisfaction, effect of financial compensation on job satisfaction, effect of job satisfaction on turnover, effect of job satisfaction on workweek, and effect of job satisfaction on productivity. Regressions are performed to estimate the non-linear relationships as opposed to a linear model specification.

15.3 Methodological Contributions

This dissertation demonstrates how the system dynamics simulation method can be used for theory building and for guiding empirical testing in SHRM/HPWS through four iterative steps shown in Figure 4.1 reprinted below.
1. **System Dynamics Model Building**: to open the black box generating the correlation observations, system dynamics is used to build a causal process model of how HR practices, through various causal paths, lead to firm performance. The model is constructed based on existing theoretical and empirical findings in the literature. This process allows one to clarify and test the causal logic of existing theories by turning verbal theories into formal mathematical models. If we find incompleteness or inconsistency, it allows us to identify the gap and to propose new theories. Sastry's (1997) formal model of punctuated equilibrium helps identify gaps in the original theory and provides a refined theory. Similar approaches could be applied to SHRM/HPWS.

When there are gaps in the causal mechanisms found in the existing literature, one can conduct qualitative field research to map out the actual causal process. This engages the grounded theory building approach (Glaser and Strauss 1967) to generate new theory when the existing theory is unclear. Such mixed methods among quantitative regression analysis, qualitative field research and simulation methods
allow the model to draw on the strength of each method to improve our understanding of the underlying causal mechanisms.

2. **Simulation Analysis:** Once a causal model is built with a set of differential equations characterizing the causal relationships among variables, one can conduct simulation analysis by changing the independent variable that we care about, such as the profit sharing percentage. One can test how different levels of profit sharing in turn influence firm performance over time. Simulation data is generated to show the relationship between profit sharing and performance.

3. **Dynamic Theory Building:** If the simulated data confirms the previous empirical findings, one gains confidence that the model may have captured the underlying causal mechanism between profit sharing and firm performance. The model contributes to the field by providing a dynamic theory of how profit sharing leads to higher (or lower) performance.

4. **Regression Analysis:** If the simulated data does not confirm the empirical finding, this informs us that either something is missing in the model or the previous regression model was mis-specified. If one is reasonably confident about the model, one can specify the regression equation on the real data based on the causal model and collect additional data if needed. The new regression analysis can test the dynamic hypothesis from step 3 and provide further empirical evidence.

   It may well be that the system dynamics model is mis-specified. Perhaps a function is not correctly estimated, or a feedback loop is missing from the model. One can conduct further field research and data collection to revise the system dynamics model and propose a new dynamic theory.

   This process not only allows us to identify gaps in the existing theory, but also enables the generation of new theories that can then be tested empirically using regression analysis. The iterative process goes on (as illustrated by the circular loop
above) between empirical testing and theory building. As a result, our understanding of the underlying causal mechanisms improves over time.

15.4 Teaching Contribution

I hope the dissertation can inform practitioners such as entrepreneurs, managers, employees and investors regarding the dynamic effects of HPWS and shared capitalism practices and help them become aware of the various conditions under which shared capitalism improves employee well-being and firm performance. To aid teaching, a computer simulation game called “Clean Technology Startup Management Flight Simulator” is developed for teaching students and training practitioners the dynamic strategies of employee ownership management in a clean technology startup company. In a safe and rapid feedback simulation environment, people can test their assumptions, examine their mental models and gain new insights that could help them design an effective HPWS.
16. DIRECTIONS FOR FURTHER RESEARCH

16.1 Further Analysis of Model

- Managerial Objectives: there are different objectives managers could define as success: quarterly net income, cumulative profit, market capitalization, stock price, founder’s net worth, employee net worth, employee job satisfaction and customer satisfaction. Future work could analyze the optimal strategic choices under various objectives. How to design HR practices and shared capitalism policies for a founder who wants to maximize her net worth versus creating the highest firm valuation? What about maximizing short-term quarterly net income versus long-term cumulative profit? Focusing on shareholder value, customer satisfaction or employee well-being has different strategic implications. Further analysis of the model could shed light on the organizational design for different objectives. It could guide inquiry into the purpose of business organizations – how to balance various objectives and in what sequence? For example, SAIC believes in putting employee well-being first, and that shareholder value will follow (Beyster and Economy 2007). This model could enable would-be entrepreneurs to test strategies under various organizational purposes.

- Dynamic Optimization: while the current analysis shows that under various conditions employee ownership improves firm performance, it does not analyze the optimal strategy in each condition. Further analysis could include dynamic optimization of the various HR practices by taking the optimal decisions at time T and feeding them into the next period to calculate the next set of optimal decisions iteratively. This could provide a trajectory of how optimal decisions change over time and potentially offer a set of optimized dynamic decision rules under various conditions.
16.2 Further Empirical Studies of the Model

- Detailed Calibration with Time-Series Data: as mentioned earlier, the current model is calibrated to the initial parameters of a startup company, Alpha Inc. Given that Alpha Inc. is at the early stage, there is no meaningful time-series data available for model calibration. Future work could collect time-series data from a mature company since its startup phase and calibrate to build further confidence in the model.

- Empirical Testing of the Propositions: this thesis serves as a theory-building study and offers eleven propositions from the simulation analysis. Some propositions confirm previous empirical findings. Others offer insights that are new. The next stage of research is to conduct empirical studies of the propositions. This can be done through regression analysis based on large-scale survey and financial data to test some of the relationships stipulated in this thesis.

- Case Studies of the Propositions: in addition to survey data, the field of SHRM/HPWS could also benefit from case studies of companies adopting various forms of high performance work practices and shared capitalism policies. One could use the propositions as a guide and research case studies that either confirm or disconfirm the propositions. This will provide further empirical evidence to guide the next iteration of model development and analysis.

16.3 Further Development of Model

- Disaggregation of Employee Ownership Recipients: the current model assumes equal distribution of stock options and stock grants when they are awarded; there is no distinction of which employees own the stocks. Further work could disaggregate the employees into the ones who are awarded stocks versus the ones who are not. This can illuminate the inter-organizational dynamics of employee ownership policy such as the issues of fairness between the haves and have-nots, the new versus old employees, etc. Without proper and fair distribution, awarding
employees stock could cause adverse effects to job satisfaction and productivity. While this study focuses on the aggregated effect of employee ownership at the firm level, future study could focus on the inter-organizational dynamics of employee ownership policy at the group level.

- Decision Rules of Employee Compensation: the decision rules for setting salary, stock options, stock grants and profit sharing are exogenously determined in the current model. Further model development could endogenize HR managers' decision rules based on various employee behavior and firm performance indicators. Should one compensate employees based on the overall financial performance or their individual impact on the financial bottom line? With a disaggregated workforce, one could study individual versus team-based performance evaluation and test some of the hypotheses proposed in the differentiated workforce literature (Becker, Huselid and Beatty 2009).

- Effect of Going Public: the current model does not distinguish between a private and a public company. Future work could model the pressure of meeting quarterly earnings targets on managerial decisions, such as employee compensation, employee ownership and participation efforts.

- Disaggregation of Competition: the current model assumes one competitor, the traditional HVAC systems with no energy efficiency savings. In reality, many startups are competing in the energy efficiency market. While the current model does have the indexed firm structure that allows the modeling of multiple firms, this thesis focuses on the dynamics between a single startup and the incumbent. Future work could analyze the competitive dynamics between multiple startups with different product development, human resource policies, financing and market strategies. One could also study how competitive pressure influences human resource decisions.
• Disaggregation of Participation Process: the current model aggregates the participation process into a stock called Participation Experience. In reality, the process to build a participatory culture is much more complex. According to Rosen and Rodgers (2007) mentioned in Section 2.1, to build participatory culture, besides awarding stocks, one needs ownership education teaching people how the ownership plan works, training people in business literacy, sharing performance data about how the company is doing overall and how each work group contributes to that, and building employee involvement not just by allowing employees to contribute ideas and information but by making that part of their everyday work through teams, feedback opportunities, devolution of authority, and other structures. Further work could model various participation processes to study the conditions for building a successful participation culture.

• Employee Ownership Program: the current model models the generic stock options and stock grants without distinguishing different types of employee ownership programs. Further work could model different program designs such as ESOP, ESPP and their tax implications to analyze the differences among various employee ownership programs.

• Union and Labor Market: the current model does not consider the effect of labor unions nor the wider labor market conditions on the adoption of shared capitalism policies. These can be explored by further work.

• Intrinsic Job Satisfaction: the current model assumes job satisfaction is driven by financial compensation, psychological ownership, participation, burnout and job security effects. Further work could model the intrinsic drivers of job satisfaction such as the meaning of the work, purpose of the organization, organizational citizenship behavior, personal growth and development.

• Debt Financing: the current model’s financing sources include the founder’s initial investment, venture capital, government grants, employee ownership

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financing and initial public offering. There is no debt financing in the model. Further work could include debt financing structures and study the tradeoff between equity versus debt financing.

- Generic Model: the current model offers a detailed structure for a clean technology firm. To make the model analysis and application go beyond the clean technology sector, one could create a generic version of a startup company by distilling the core structure from the current model. One could set key parameters, such as product development time and sales cycle, to represent various industry conditions. For example, a software company has a shorter product development time and sales cycle than a bio-tech company. A generic model could study various HR practices under different industry settings.

16.4 Final Words

How to create a high performance work system that improves employee well-being and firm performance? This dissertation sheds light on the importance of combining “soft” HR practices, such as employee participation, along with the “hard” compensation policies, such as employee ownership and profit sharing. Being aware of the conditions under which shared capitalism works could ease fears such as the fear of equity dilution and enable organizations to create wealth by sharing it. By expanding the pool of capitalists and empowering employees to share the wealth they contribute to creating, shared capitalism may be able to become a sustainable and predominant form of capitalism.
APPENDIX: MODEL DOCUMENTATION

**************************************************************

.Employee Participation
**************************************************************

Average Participation[vendor, department]=ZIDZ((Average Rookie Participation[vendor,department]*Rookie Employees[vendor,department]+Average Senior Participation[vendor,department]*Experienced Employees[vendor,department]), (Rookie Employees[vendor,department]+Experienced Employees[vendor,department])))

~ Hours
~ Employees' average accumulated participation experience in hours.

Average Participation Experience Needed for Participation Culture=100
~ Hours
~ Maximum average participation hours needed for the whole company to reach a complete participatory culture. This is a theoretical construct. 100 hours means employees need to constantly accumulated 100 hours of participation experience (given there is participation loss rate) in order to achieve a complete participatory culture.

Average Rookie Participation[vendor,department]=ZIDZ(Rookie Employees Participation Experience[vendor,department], Rookie Employees[vendor,department])
~ Hours
~ Average rookies' participation experience (in hours).

Average Senior Participation[vendor,department]=ZIDZ ( Experienced Employees Participation Experience[vendor,department], Experienced Employees[vendor,department] )
~ Hours
~ Average experienced employees' participation experience (in hours).

Effect of Work Pressure on Participation Time per Employee[vendor, department]=1+Sensitivity of Work Pressure on Participation Time*(Function of Work Pressure on Participation Time per Employee(Work Pressure[vendor,department])-1)
~ Dimensionless

Experienced Employees Participation Experience[vendor,department]= INTEG (Senior Participation Effort[vendor,department]+Participation Assimilation Rate[vendor,department] - Loss of Participation from Experienced Quit Rate[vendor,department] - Loss of Participation from Senior Layoff[vendor,department] - Senior Participation Experience Loss Rate[vendor,department],0)
~ Person*Hours
~ The cumulative total experience of all senior employees, in person-hours. Increased as rookies become experienced (senior) employees and as the senior employees continue to learn from their experience. Decreased when senior employees quit or are laid off.

Function of Work Pressure on Participation Time per Employee[(1,0), (3,1), (1,1), (1.25,0.94), (1.5,0.83), (1.75,0.67), (2,0.5), (2.25,0.32), (2.5,0.17), (2.75,0.06), (3,0)]
~ Dimensionless
~ As work pressure > 1 (desired work effort greater than available work effort), people start to cut down the participation time as "real work" takes priority.

Loss of Participation from Experienced Quit Rate[vendor,department]=Average Senior Participation[vendor,department] * Experienced Quit Rate[vendor,department]
~ Person*Hours/Year

Loss of Participation from Rookie Layoff Rate[vendor,department]=Average Rookie Participation[vendor,department] * Rookie Layoff Rate[vendor,department]
Person* Hours/Year

Loss of Participation from Rookie Quit Rate[vendor,department]=Average Rookie Participation[vendor,department] *  
Rookie Quit Rate[vendor,department]  
~ Person*Hours/Year

Loss of Participation from Senior Layoff[vendor,department]=Average Senior Participation[vendor,department] *  
Experienced Layoff Rate[vendor,department]  
~ Person*Hours/Year

Normal Participation Time per Employee=0  
~ Hours/Year [0,100,10]  
~ Normal participation time is assumed to be 2 hour per week.

Participation Assimilation Rate[vendor,department]=Assimilation Rate[vendor,department] * Average Rookie Participation[vendor,department]  
~ Person*Hours/Year  
~ Rookie Experience lost when rookies becomes experienced.

Participation Culture[startup]=MIN(1, SUM(Participation Culture by Department[startup,department]) * Total Employees per Department[startup,department])/SUM(Total Employees per Department[startup,department]))  
~ Dimensionless

Participation Experience Loss Time=3  
~ Year

Participation Time[vendor]=SUM(Participatory Time per Employee[vendor,department]) * Total Employees per Department[vendor,department])/SUM(Total Employees per Department[vendor,department])  
~ Hours/Year

Rookie Employees Participation Experience[vendor,department]= INTEG (Rookie Participation Effort[vendor,department] - Participation Assimilation Rate[vendor,department] - Loss of Participation from Rookie Layoff Rate[vendor,department] - Loss of Participation from Rookie Quit Rate[vendor,department] - Rookie Participation Experience Loss Rate[vendor,department],0)  
~ Person*Hour/Year  
~ Cumulative participation effort of rookie employees, in person-hours. Increased as senior employees spend time on participation effort per rookie, e.g. committee, open door policy, evaluate and implement ideas. Decreased as rookies become experienced (senior) employees and when rookies quit or are laid off.

Rookie Participation Experience Loss Rate[vendor, department]=Rookie Employees Participation Experience[vendor,department]/Participation Experience Loss Time  
~ Person*Hour/Year

Senior Participation Experience Loss Rate[vendor, department]=Experienced Employees Participation Experience[vendor,department]/Participation Experience Loss Time  
~ Person*Hour/Year

Sensitivity of Work Pressure on Participation Time=0  
~ Dimensionless [0,1,0.1]

**************************************************************************
Employee Hiring and Experience
**************************************************************************

Average Years of Total Employee Experience[vendor]=ZIDZ(SUM(Rookie Employees Experience[vendor,department]+Experienced Employees Experience[vendor,department])/Total Employees[vendor])/Normal Work Hours per Year

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Industry Quit Fraction = 0.1

Initial Rookie Experience in Years[vendor,department] = 0.5

Layoff as Percentage of Total Employees[vendor] = Quarterly Total Layoff[vendor] / Total Employees[vendor] * 100

Quit Fraction[vendor,department] = Industry Quit Fraction * Effect of Job Attractiveness on Quit Rate[vendor,department]

Sensitivity of Job Attractiveness on Quits = 1

Sensitivity of Job Attractiveness on Time to Fill Vacancies = 1

Turnover as Percentage of Total Employees[vendor] = (SUM(Quarterly Quits[vendor,department]), Total Employees[vendor]) * 100

Assimilation Time = 2

Average Employee Experience[vendor,department] = (Rookie Employees Experience[vendor,department] + Exposed Employees Experience[vendor,department]) / Total Employees per Department[vendor,department]

Average Layoff Time = 0.166

Avg Time to Fill Employee Vacancies[department] = 0.167

Bankruptcy Layoff Rate[vendor,department] = Bankruptcy Switch[vendor] * ((Rookie Employees[vendor,department] / TIME STEP) - Rookie Quit Rate[vendor,department] - Assimilation Rate[vendor,department])

Desired Layoff Rate[vendor,department] = Switch for Layoffs * MAX (0, - Indicated Employee Hiring Rate[vendor,department])

Employee Vacancies[vendor,department] = INTEG( Employee Vacancy Creation Rate[vendor,department] - Employee Vacancy Closure Rate[vendor,department] - Employee Vacancy Cancellation Rate[vendor,department], Desired Employee Vacancies[vendor,department])

~ Year

~ 1/Year

~ Year

~ Dimensionless

~ 1/Year

~ Dimensionless [0, 2, 0.1]

~ Dimensionless [0, 2, 0.1]

~ Dimensionless

~ Total number of turnover as a percentage of total employees.

~ Year

~ Hours

~ Average experience of all rookie and experienced employees by department.

~ Year

~ The average time required to lay off an employee.

~ Year

~ The average time required to fill vacancies and hire new people.

~ People/Year

~ Layoff rate when firm bankrupts, which equals all existing rookies minus those that quit and assimilate.

~ Persons/Year

~ If hiring rate is negative, means we want to get rid of sales people as long as we're willing to make lay offs

~ People

~ The number of open sales positions the firm seeks to fill.
Experience Assimilation Rate[vendor,department] = Assimilation Rate[vendor,department] * Average Rookie Experience[vendor,department]
   ~ Persons*Hours/Year
   ~ Rookie Experience lost when rookies becomes experienced.

   ~ Person*Hours
   ~ The cumulative total experience of all senior employees, in person-hours.
   Increased as rookies become experienced (senior) employees and as the senior employees continue to learn from their experience. Decreased when senior employees quit or are laid off.

Increase in Experience From Hiring[vendor,department] = Rookie Hire Rate[vendor,department] * Average Experience Of New Hires[vendor,department]
   ~ Persons*Hours/Year
   ~ Experience gain from hiring

Increase in on the Job Experience from Experienced[vendor,department] = Experienced Employees[vendor,department] * Working Hours per Year[vendor,department]
   ~ Person*Hours/Year
   ~ Employees gain one hour of experience per hour worked.

Increase In on the job Experience from Rookie[vendor,department] = Rookie Employees[vendor,department] * Learning per Hour for Rookies[vendor,department] * Working Hours per Year[vendor,department]
   ~ Person*Hours/Year
   ~ Rookie employees do not receive the full range of experiences as senior employees so the effective experience they gain per hour worked is less than one hour.

Indicated Employee Hiring Rate[vendor,department] = Adjustment for Labor Force[vendor,department] + Total Quit Rate[vendor,department]
   ~ People/Year
   ~ Hire enough people to replace expected attrition and adjust the number of employees to the desired level.

Loss of Experience from Experienced Quit Rate[vendor,department] = Average Senior Experience[vendor,department] * Experienced Quit Rate[vendor,department]
   ~ Person*Hours/Year

Loss of Experience from Layoff[vendor,department] = Average Senior Experience[vendor,department] * Experienced Layoff Rate[vendor,department]
   ~ Person*Hours/Year

Loss of Experience from Rookie Layoff Rate[vendor,department] = Average Rookie Experience[vendor,department] * Rookie Layoff Rate[vendor,department]
   ~ Person*Hours/Year

Loss of Experience from Rookie Quit Rate[vendor,department] = Average Rookie Experience[vendor,department] * Rookie Quit Rate[vendor,department]
   ~ Person*Hours/Year

Maximum Experienced Layoff Rate[vendor,department] = Experienced Employees[vendor,department] / Average Layoff Time
   ~ People/Year

Maximum Rookie Layoff Rate[vendor,department] = Rookie Employees[vendor,department] / Average Layoff Time
   ~ People/Year
   ~ Maximum rookie layoff rate is determined by the number of rookie employee
and the layoff time.

Rookie Employees Experience[vendor,department] = INTEG( Increase in Experience From Hiring[vendor,department] + Increase In on the job Experience from Rookie[vendor,department] - Experience Assimilation Rate[vendor,department] - Loss of Experience from Rookie Layoff Rate[vendor,department] - Loss of Experience from Rookie Quit Rate[vendor,department], Initial Rookie Employees[vendor,department] * Average Experience Of New Hires[vendor,department] )

~ Person*Hours
~ Cumulative experience of rookie employees, in person-hours. Increased as the rookies employees continue to learn from their job experience. Decreased as rookies become experienced (senior) employees and when rookies quit or are laid off.

Rookie Fraction[vendor]=ZDZ(SUM ( Rookie Employees[vendor,department] ), Total Employees[vendor])
~ Dimensionless
~ Total rookies as a fraction of total employees.

Rookie Fraction by Department[vendor,department]=ZDZ(Rookie Employees[vendor,department], ( Rookie Employees[vendor,department] + Experienced Employees[vendor,department]))
~ Dimensionless
~ Rookie as a fraction of total employees in each department.

Switch for Layoffs = 1
~ Dmnl [0,1,1]
~ Whether or not to allow layoffs to occur (0=no, 1=yes)

Average Years of Employee Experience[vendor, department]=ZDZ((Rookie Employees Experience[vendor,department]+Experienced Employees Experience[vendor,department]), (Rookie Employees[vendor,department]+Experienced Employees[vendor,department]))/Normal Work Hours per Year
~ Year
~ Average years of employee experience by department.

Average Years of Rookie Experience[vendor, department]=Average Rookie Experience[vendor,department]/Normal Work Hours per Year
~ Year

Average Years of Senior Experience[vendor, department]=Average Senior Experience[vendor,department]/Normal Work Hours per Year
~ Year

Average Experience Of New Hires[vendor,department]=Initial Rookie Experience in Years[vendor, department]*Normal Work Hours per Year
~ Hours
~ Average relevant experience of new sales hires

Initial Engineers[vendor]=5
~ People [0,10,1]

Initial Experience of Senior Employees[vendor,department]=(Initial Rookie Experience in Years[vendor,department]+Assimilation Time)*Normal Work Hours per Year
~ Hours
~ The initial experience level of senior (experienced) employees, in hours.

Initial Sales Force[vendor]=0
~ People [0,10,1]

Effect of Job Attractiveness on Quit Rate[vendor,department]=Sensitivity of Job Attractiveness on Quits*Function for Effect of Job Attractiveness on Quits(Job Attractiveness for Existing Employees[vendor,department])
~ Dimensionless
~ The effect of job attractiveness on the actual quit rate per year.
Effect of Job Attractiveness on Time to Fill Vacancies \( = 1 + \text{Sensitivity of Job Attractiveness on Time to Fill Vacancies} \times \text{Function for Effect of Job Attractiveness on Time to Fill Vacancies} \times \text{Job Attractiveness for New Hires} \times \text{Department} \)

- Dimensionless
- Effect of financial rewards on time to hire people.

Function for Effect of Job Attractiveness on Quits \( = (1, 2), (1.3, 3.639), (1.6, 4.808), (1.9, 3.909), (2.2, 2.996), (2.5, 2.136), (2.8, 1.396), (3, 1), (3.1, 0.8234), (3.3, 0.55), (3.4, 0.4305), (3.7, 0.1958), (4, 0.07603) \)

- Dimensionless
- The higher the job attractiveness, the lower the actual quit rate. Estimated using NBER Shared Capitalism dataset of 38,000 samples.

Function for Effect of Job Attractiveness on Time to Fill Vacancies \( = (2, 0) - (3.5, 10), (2, 10), (2.1, 4), (2.2, 3), (2.3, 2.3), (2.4, 1.8), (2.5, 1.55), (2.6, 1.35), (2.7, 1.2), (2.8, 1.1), (2.9, 1.05), (3, 1), (3.1, 0.85), (3.2, 0.77), (3.3, 0.7), (3.4, 0.6), (3.5, 0.5) \)

- Dimensionless
- Higher the job attractiveness, shorter the hiring time, cap at minimum hiring time equals to 30% of reference time. When job attractiveness is below 1, the firm cannot find anyone to work for it.

Time to Fill Employee Vacancies \( = \text{Avg Time to Fill Employee Vacancies (department)} \times \text{Effect of Job Attractiveness on Time to Fill Vacancies} \times \text{Department} \)

- Year
- Actual time to hire people is the average time multiple by the effect of financial rewards on hiring time.

Employee Quality

- Quality of Total New Hires \( = \text{SUM(Quality Of New Hires (vendor, department))}/2 \)

- Quality of new hires from all departments.

Sensitivity of Job Attractiveness on Quality of New Hires \( = 1 \)

- Dimensionless \([0, 2, 0.1]\)

Assimilation Rate \( = \text{Rookie Employees (vendor, department)} \times \text{Company in Operation Switch (vendor) / Assimilation Time} \)

- Persons/Year

Average Quality Of New Hires \( = 1 \)

- Quality of new hires, this is the quality of people prior coming to the firm, including innate ability, education etc.

Effect of Job Attractiveness on Quality of New Hires \( = 1 + \text{Sensitivity of Job Attractiveness on Quality of New Hires} \times \text{Function for Effect of Job Attractiveness on Quality of New Hires} \times \text{Job Attractiveness for New Hires} \times \text{Department} \)

- Dimensionless
- Effect of financial reward on quality of people attracted. Higher the compensation, higher the quality of new hires.

Experienced Employees Quality \( = \text{INTEG} (\text{Quality Assimilation Rate (vendor, department)} - \text{Loss of Quality from Experienced Quit Rate (vendor, department)} - \text{Loss of Quality from Layoff (vendor, department)} - \text{Initial Experienced Employees (vendor, department)} \times \text{Average Quality Of New Hires (vendor, department)}) \)

- Person^quality
- The cumulative total experience of all senior employees, in person-hours. Increased as rookies become experienced (senior) employees and as the senior employees continue to learn from their experience. Decreased when
senior employees quit or are laid off.

Experienced Layoff Rate[vendor,department] = MIN ( Maximum Experienced Layoff Rate[vendor,department] , MAX ( 0, Desired Layoff Rate[vendor,department] - Rookie Layoff Rate[vendor,department] ) ) People/Year

~ Layoffs, if necessary, occur in reverse seniority order. Hence layoffs are the smaller of the maximum rate at which experienced people can be laid off (based on the time required to carry out a force reduction) or the difference between the desired total rate of layoffs and the rate of rookie layoffs. This difference will be zero if all needed layoffs are accommodated by firing rookies, and will be positive if the rate of rookie layoff is not sufficient. It cannot be negative since rookie layoffs will be at most the total desired layoff rate.

Experienced Quit Rate[vendor,department]=Experienced Employees[vendor,department] * Quit Fraction[vendor,department]

~ People/Year

Function for Effect of Job Attractiveness on Quality of New Hires\([(2,0)-(4,2)],(2,0.6),(2.2,0.61),(2.4,0.63),(2.6,0.7),(2.8,0.83),(3,1),(3.2,1.17),(3.4,1.35),(3.6,1.45),(3.8,1.49),(4,1.5)\]

~ Dimensionless

~ Higher the compensation, higher the quality of new hires.

Increase in Quality From Hiring[vendor,department]=Rookie Hire Rate[vendor,department] * Quality Of New Hires[vendor,department]

~ quality*Person/Year

~ Quality gain from hiring

Initial Experienced Employees[vendor,sales] = Initial Sales Force[vendor]
Initial Experienced Employees[vendor,engineer] = Initial Engineers[vendor]

~ People

Initial Rookie Employees[vendor,department]=0

~ Persons \([0,20,1]\)

~ Number of sales people company initially has

Loss of Quality from Experienced Quit Rate[vendor,department]=Average Senior Quality by Department[vendor,department] * Experienced Quit Rate[vendor,department]

~ Person*quality/Year

Loss of Quality from Layoff[vendor,department]=Average Senior Quality by Department[vendor,department] * Experienced Layoff Rate[vendor,department]

~ Person*quality/Year

Loss of Quality from Rookie Layoff Rate[vendor,department]=Average Rookie Quality by Department[vendor,department] * Rookie Layoff Rate[vendor,department]

~ Person*quality/Year

~ Loss of quality when rookies are layoff.

Loss of Quality from Rookie Quit Rate[vendor,department] = Average Rookie Quality by Department[vendor,department] * Rookie Quit Rate[vendor,department]

~ Person*quality/Year

~ Loss of quality when rookies quit.

Quality Assimilation Rate[vendor,department]=Assimilation Rate[vendor,department]* Average Rookie Quality by Department[vendor,department]

~ Persons*quality/Year

~ Quality lost when rookies becomes experienced.

Quality Of New Hires[vendor,department]=Average Quality Of New Hires[vendor,department]*Effect of Job Attractiveness on Quality of New Hires[vendor,department]

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Actually quality of new hires is the average quality times the effect of financial rewards on quality. The higher the financial rewards, the better quality people is attracted.

- Person*quality
- Cumulative quality of rookie employees. Decreased as rookies become experienced (senior) employees and when rookies quit or are laid off.

Rookie Layoff Rate[vendor,department] = MAX ( Bankruptcy Layoff Rate[vendor,department] , MIN ( Desired Layoff Rate[vendor,department] , Maximum Rookie Layoff Rate[vendor,department] ) )
- People/Year

Rookie Quit Rate[vendor,department]= Quit Fraction[vendor,department]* Rookie Employees[vendor,department]
- Persons/Year
- Rate at which sales people leave (quit)

Average Employee Quality[vendor]=ZDZ(SUM(Rookie Employees Quality[vendor,department]!)+Experienced Employees Quality[vendor,department]!), Total Employees[vendor])
- quality
- Average quality of all employees.

Average Rookie Quality[vendor]=ZDZ(SUM(Rookie Employees Quality[vendor,department]!), SUM(Rookie Employees[vendor,department]!))
- quality
- Average quality of rookies from all departments.

Average Senior Quality[vendor]=ZDZ(SUM(Experienced Employees Quality[vendor,department]!), SUM(Experienced Employees[vendor,department]!))
- quality
- Average quality from experienced employees of all departments.

Aggressiveness of Hiring Policy=1
- Dimensionless [0,1]

Change in Desired Employees[vendor]=Desired Employees from Policy[vendor]*(Desired Employee Growth Percentage Policy/100)
- People/Year

Desired Employee Growth Percentage Policy=0
- 1/Year [0,100,1]

Desired Employee Proportion[vendor, sales]=ZDZ(Desired Sales Force[vendor], Desired Total Employees[vendor])
Desired Employee Proportion[vendor, engineer]=ZDZ(Desired Engineers[vendor], Desired Total Employees[vendor])
- Dimensionless

Desired Employee Proportion from Game[vendor,engineer]= GAME (Desired Employee Proportion[vendor,engineer]* 100)
Desired Employee Proportion from Game[vendor, sales]=100-Desired Employee Proportion from Game[vendor, engineer]
- Dimensionless [0,100,5]

Desired Employees from Policy[vendor]= INTEG (Change in Desired Employees[vendor],Total Employees[vendor])
Desired Total Employees[vendor]=Desired Engineers[vendor]+Desired Sales Force[vendor]

Desired Total Employees from Game[vendor]=Starting Total Employees[vendor] *(1+Percentage of Desired Total Employee Growth from Game/Percentage Point)

Feasible Headcount[vendor, department]=ZID2(Headcount Budget[vendor, department], Average Salary by Department[vendor, department])

Headcount Budget[vendor, department]=Total Headcount Budget[vendor]*Desired Employee Proportion from Game[vendor, department]/100

Headcount Budget Adjustment Time=1

Headcount Budget as Fraction of Working Capital=0.8

Indicated Desired Total Employees[vendor]=IF THEN ELSE(Switch for Game=1, Desired Total Employees from Game[vendor], IF THEN ELSE(Switch for Hiring Policy=1, Desired Employees from Policy[vendor], Desired Total Employees[vendor]))

Min Runway for Paying Employee[vendor]=2

Percentage of Desired Total Employee Growth from Game = GAME(0)

Percentage Point=100

Starting Total Employees[vendor]=SAMPLE IF TRUE(MODULO(Time, 0.25) < TIME STEP, Total Employees[vendor], Total Employees[vendor])

Switch for Hiring Policy=IF THEN ELSE(Desired Employee Growth Percentage Policy=0, 0, 1)

Total Headcount Budget[vendor]=SMOOTH(ZID2(Headcount Budget as Fraction of Working Capital*Working Capital[vendor], Min Runway for Paying Employee[vendor]), Headcount Budget Adjustment Time)

Adjustment for Employee Vacancies[vendor, department] = ( Desired Employee Vacancies[vendor, department] - Employee Vacancies[vendor, department] ) / Employee Vacancy Adjustment Time[vendor]

Adjusts sales vacancy creation to have the desired number of vacancies.
Adjustment for Labor Force[vendor,department] = (Authorized Headcount[vendor,department] - Total Employees per Department[vendor,department]) / Labor Force Adjustment Time[vendor]
  ~ Persons/Year
  ~ Adjustment for sales and engineers from their current numbers to the authorized headcount numbers.

Authorized Headcount[vendor,department] = MIN(Indicated Desired Employee[vendor,department], Feasible Headcount[vendor,department]) * Effect of Liquidity on Headcount[vendor] * Aggressiveness of Hiring Policy
  ~ People

Desired Employee Vacancies[vendor,department] = MAX(0, Avg Time to Fill Employee Vacancies[department] * Indicated Employee Hiring Rate[vendor,department])
  ~ People

Desired Employee Vacancy Cancellation Rate[vendor,department] = MAX(0, - Desired Employee Vacancy Creation Rate[vendor,department])
  ~ Persons/Year
  ~ The desired rate of sales vacancy cancellation, given by the desired vacancy creation rate whenever that rate is negative.

Desired Employee Vacancy Creation Rate[vendor,department] = Indicated Employee Hiring Rate[vendor,department] + Adjustment for Employee Vacancies[vendor,department]
  ~ Persons/Year
  ~ Create enough sales vacancies to result in the desired hiring rate, adjusted to bring the stock of vacancies in line with the desired level.

Effect of Liquidity on Headcount[vendor] = Function for Effect of Liquidity on Headcount (Perceived Liquidity[vendor])
  ~ Dimensionless

Employee Vacancy Adjustment Time[vendor] = 0.167
  ~ Year
  ~ The average time over which to adjust the actual number of sales vacancies to the desired level.

Employee Vacancy Cancellation Rate[vendor,department] = MIN(Desired Employee Vacancy Cancellation Rate[vendor,department], Max Employee Vacancy Cancellation Rate[vendor,department])
  ~ Persons/Year
  ~ The rate at which to cancel existing sales vacancies prior to filling them.

Employee Vacancy Cancellation Time[vendor] = 0.167
  ~ Year
  ~ The average time required to cancel an employee vacancy.

Employee Vacancy Closure Rate[vendor,department] = Rookie Hire Rate[vendor,department]
  ~ Persons/Year
  ~ Vacancies are closed when the employee is hired

Employee Vacancy Creation Rate[vendor,department] = MAX(0, Desired Employee Vacancy Creation Rate[vendor,department])
  ~ Persons/Year
  ~ The rate at which to create new sales positions and begins to recruit for them.

Function for Effect of Liquidity on Headcount([[0,0)-(1,1)],(0,0),(0.2,0.5),(0.4,0.8),(0.6,0.9),(0.8,0.98),(1,1),(1000,1))
  ~ Dimensionless
  ~ Low liquidity forces the firm to cut the fraction of revenue it plans to spend on headcount.

Indicated Desired Employee[vendor,department] = Indicated Desired Total Employees[vendor] * Desired Employee Proportion from Game[vendor,department] / 100
  ~ People
  ~ Desired employees depending on whether the game is on or not, if not, take
inputs from endogenously driven values.

Max Employee Vacancy Cancellation Rate[\text{vendor,department}] = \frac{\text{Employee Vacancies[vendor,department]}}{\text{Employee Vacancy Cancellation Time[vendor]}}

\sim \text{Persons/Year}

\sim \text{The maximum sales vacancy cancellation rate is determined by the number of vacancies outstanding and the minimum cancellation time.}

Labor Force Adjustment Time[\text{vendor}] = 0.25

\sim \text{Year [0,90,1]}

\sim \text{The time period over which the firm seeks to bring the sales force in line with the desired level.}

Customer Support

Customer Support as Fraction of Total Engineering Effort[\text{vendor}] = \text{ZIDZ}(\text{Customer Support Effort[vendor]}, \text{Effective Engineering Effort[vendor]})

\sim \text{Dimensionless}

Effective Engineering Effort[\text{vendor}] = \text{Rookie Effective Work Effort[vendor,engineer]} + \text{Experienced Work Effort for Non Administrative Work[vendor,engineer]}

\sim \text{Persons*Hours/Year}

\sim \text{How many total hours engineers work per year net of coaching and financing efforts.}

Customer Support Effort for Game[\text{vendor}] = \text{Effective Engineering Effort[vendor]} \times (\text{Customer Support Proportion for Game[vendor]/100})

\sim \text{Hours*Person/Year}

Customer Support Proportion for Game[\text{vendor}] = \text{GAME (0)}

\sim \text{Dimensionless [0,100]}

Desired Customer Support as Fraction of Engineering Effort[\text{vendor}] = \text{MAX}(\text{Min Customer Support Fraction[vendor]}, \text{ZIDZ}(\text{Desired Customer Support[vendor]}, (\text{Desired Customer Support[vendor]} + \text{Desired Product Development Effort[vendor]})))

\sim \text{Dimensionless}

\sim \text{desired customer support as fraction of total engineer efforts that include product development and customer support, constrained by the min customer support fraction.}

Min Customer Support Fraction[\text{vendor}] = 1

\sim \text{Dimensionless [0,1]}

\sim 1 \text{ means customer support is a priority to product development.}

Switch for Customer Support Game Input[\text{vendor}] = 0

\sim \text{Dimensionless [0,1,1]}

Desired Product Development Effort[\text{vendor}] = \text{SUM} (\text{Desired Feature Development Rate[\text{vendor,featuretype}] \times Engineer Hours Required per Feature[\text{featuretype}]})

\sim \text{Persons*Hours/Year}

\sim \text{How many person hours are needed to develop the features we desire}

Appropriable Development Fraction = 1 - \text{Nonappropriable Development Fraction}

\sim \text{Dimensionless}

Customer Support Effort[\text{vendor}] = (1 - \text{Switch for Customer Support Game Input[\text{vendor}]}) \times \text{MIN}(\text{Desired Customer Support[\text{vendor}], Feasible Customer Support[\text{vendor}]} \times \text{Switch for Customer Support Game Input[\text{vendor}]})

\sim \text{Persons*Hours/Year}

\sim \text{After allocating the min percentage of engineering effort to development, then use engineering effort to satisfy customer support (current engineering) needs}
Customer Support Needed per Adopter = 45

\[
\text{Person-Hours needed per year needed to support each adopter. 0.02 ppl/year x 2000 hour/year}
\]

Desired Customer Support [customer] = Adopters [customer] \ast \text{Customer Support Needed per Adopter} \ast \text{Switch for Customer Support}

\[
\text{Persons\ast Hours/Year}
\]

Total cust support needed for customers who have purchased and adopted the product (includes time needed to deliver the product)


\[
\text{Person\ast Hours/Year}
\]

Feasible Customer Support [vendor] = Effective Engineering Effort [vendor] \ast \text{Desired Customer Support as Fraction of Engineering Effort [vendor]}

\[
\text{Person\ast Hours/Year}
\]

Remaining engineering effort after allocating to the min effort for development.

Customer Support Shortage Fraction [vendor] = \text{ZIDZ} \left( \left( \text{Desired Customer Support [vendor]} - \text{Customer Support Effort [vendor]} \right), \text{Desired Customer Support [vendor]} \right)

\[
\text{Dimensionless}
\]

The shortage of available engineering effort from the customer support needed as a ratio of the customer support needed.

Nonappropriable Development Fraction = 0.909

\[
\text{Dimensionless}
\]

Fraction of development effort applied to non-appropriable features (as opposed to appropriable features). 10 out of 11 is allocated to non-appropriable feature because it is worth 10 times more than appropriable features (nonappropriable feature multiple = 10).

Product Development Effort [vendor, appropriable] = Appropriable Development Fraction \ast \text{Effective Engineering Effort Net of Customer Support [vendor]}

Product Development Effort [vendor, nonappropriable] = Nonappropriable Development Fraction \ast \text{Effective Engineering Effort Net of Customer Support [vendor]}

\[
\text{Persons\ast Hours/Year}
\]

After satisfying min product development and customer support, engineering effort is allocated to additional development, differentiated between appropriate and non-appropriate features.

Switch for Customer Support = 1

\[
\text{Dimensionless} [0,1,1]
\]

0 = there is no customer support business, thus no customer support effort and revenue. 1 = there is customer support business.

Customer Service Quality [vendor] = \text{ZIDZ} \left( \text{Customer Support Effort [vendor]}, \text{Desired Customer Support [vendor]}, 1 \right)

\[
\text{Dimensionless}
\]

Fraction of max cust support effectiveness (If we don’t need any cust support, then we’re supplying all that is needed). Also amount of cust support determines how soon product is “delivered”.

Adopters [customer] = \text{INTEG}(\text{Adopter Generation Rate [customer]} - \text{Poaches [customer]}, \text{Initial Adopters})

Adopters [none] = 0

~ Prospects

~ Prospects who are now using the product

******************************************************************************

.Productivity and Work Effort
******************************************************************************

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Actual Work Effort[vendor, department] = Rookie Work Effort[vendor, department] + Experienced Work Effort[vendor, department]
  = Person*Hour/Year
  = Total actual person*hour of work effort per year from all employees, as distinguished from the effective work effort due to productivity effects.

Effect of Job Attractiveness on Productivity[vendor, department] = 1 + Sensitivity of Job Attractiveness on Productivity* (Function for Job Attractiveness on Productivity(Job Attractiveness for Existing Employees[vendor, department])-1)
  = Dimensionless

Effect of Participation Culture on Effort Needed for Managing Participation[vendor, department] = 1 + Sensitivity of Participation Managing Effort* (Function for Participation Culture on Effort Needed for Managing Participation(Participation Culture by Department[vendor, department])-1)
  = Dimensionless

Effect of Participation on Productivity[vendor, department] = IF [P] THEN ELSE[Participatory Time per Employee[vendor, department] > 0, 1 + Sensitivity of Participation on Productivity* (Function for Participation on Productivity(Participation Culture by Department[vendor, department])-1), 1)
  = Dimensionless

Effective Total Work Effort[vendor] = SUM(Effective Work Effort[vendor, department])
  = Person*Hour/Year

Employee Productivity[vendor] = ZIDZ(SUM(Effective Work Effort[vendor, department]), SUM(Actual Work Effort[vendor, department]))
  = Dimensionless
  = Employee productivity calculated as the total effective work effort divided by actual work effort.

  = Person*Hour/Year

Function for Effect of Employee Quality on Productivity([[0,0]-
(2,2)],[(0,0),(0.25,0.1),(0.5,0.33),(0.7,0.72),(0.8,0.85),(0.9,0.93),(1,1),(1.1,1.05),(1.2,1.08),(1.3,1.1),(2,1.15)])
  = Dimensionless
  = Higher the employee quality, higher the productivity.

Function for Job Attractiveness on Productivity([[1,0.5]-
(4,1.2)],[(1,0.53),(1.25,0.542982),(1.5,0.565),(1.75,0.6),(2,0.65),(2.25,0.72),(2.5,0.8),(2.75,0.9),(3,1),(3.25,1.07),(3.5,1.13),(3.75,1.17),(4,1.2)])
  = Dimensionless
  = Higher the job attractiveness, higher the productivity. It is estimated based on the NBER Shared Capitalism dataset.

Function for Participation on Productivity([[0,0.9]-
(1,1.1)],[(0,0.95),(0.1,0.96),(0.2,0.977),(0.3,1),(0.4,1.025),(0.5,1.045),(0.6,1.063),(0.7,1.075),(0.8,1.08596),(0.9,1.09298),(1,1.1)])
  = Dimensionless
  = After certain threshold of participation culture, higher participation, higher productivity.

Function of Participation Culture on Effort Needed for Managing Participation([[0,0.2]-
(1,1)],[(0,1),(0.1,0.25,0.95),(0.25,0.86),(0.375,0.75),(0.5,0.6),(0.615,0.47),(0.75,0.34),(0.875,0.25),(1,2)])
  = Dimensionless
  = When participation culture is low (start introducing participation), it takes more effort from senior managers to manage participation efforts. As the firm accumulates participatory capacity, it takes less supervising efforts.
Participation Managing Effort[vendor, department] = Total Participation Effort[vendor, department] * Effect of Participation Culture on Effort Needed for Managing Participation[vendor, department]

~ Person Hour/Year

Participatory Time per Employee[vendor, department] = Normal Participation Time per Employee * Effect of Work Pressure on Participation Time per Employee[vendor, department]

~ Hours/Year [0,1000,10]
~ Number of work hours per year allocated to participation effort, e.g. team work, problem solving group, participation committee.

Reference Quality = 1
~ quality

Rookie Participation Effort[vendor, department] = Rookie Employees[vendor, department] * Participatory Time per Employee[vendor, department]

~ Persons Hours/Year
~ Rookie employees do not receive the full range of experiences as senior employees so the effective experience they gain per hour worked is less than one hour.

Rookie Work Effort[vendor, department] = Rookie Employees[vendor, department] * Working Hours per Year[vendor, department]

~ Person Hour/Year
~ The actual person hour of work effort from rookie employees per year equals the total rookie employees times the working hours per year.

Senior Participation Effort[vendor, department] = Experienced Employees[vendor, department] * Participatory Time per Employee[vendor, department]

~ Person Hour/Year

Sensitivity of Job Attractiveness on Productivity = 1
~ Dimensionless [0,2,0.1]

Sensitivity of Participation Managing Effort = 1
~ Dimensionless [0,1,0.1]

Sensitivity of Participation on Productivity = 1
~ Dimensionless [0,2,0.1]

~ Dimensionless
~ Total senior productivity effects from senior employee equality, experience, and job attractiveness.

Total Participation Effort[vendor, department] = Senior Participation Effort[vendor, department] + Rookie Participation Effort[vendor, department]

~ Person Hour/Year

~ Dimensionless
~ Total rookie productivity effects from rookie employee equality, experience, and job attractiveness.

Average Senior Experience[vendor, department] = ZIDZ (Experienced Employees Experience[vendor, department], Experienced Employees[vendor, department])

~ Hours
~ Average experienced employees' work experience (in hours).
Effect of Rookie Employee Experience on Productivity[vendor,department] = MIN ( ( Relative Rookie Experience[vendor,department] ) ^ Employee Experience Curve Strength[vendor,department] , Max Employee Productivity from Experience )

- ~ Dmnl
- Learning curve for productivity from experience (from Sterman pg 507, from Zangwill and Kantor (1998)). Productivity will never rise above some maximum no matter how high relative experience rises.

Employee Experience Curve Strength[vendor,department] = LN ( 1 + Employee Productivity Change Per Doubling of Experience[vendor,department] ) / LN ( 2 )

- ~ Dimensionless
- The exponent in the learning curve is determined by the improvement in sales productivity per doubling of experience.

Employee Experience Reference[vendor,department]=2000

- ~ Hours
- Amount of sales experience which will produce normal productivity

Employee Productivity Change Per Doubling of Experience[vendor,department]=0.1

- ~ Dmnl
- Fractional change in productivity of people per doubling of their effective experience

Max Employee Productivity from Experience=2

- ~ Dmnl
- Max amount of productivity multiple that experience can bring


- ~ Dimensionless
- The ratio of the average experience of rookie employees to the reference level used in the learning curve.

Relative Senior Experience[vendor,department]=Average Senior Experience[vendor,department] / Employee Experience Reference[vendor,department]

- ~ Dimensionless
- The ratio of the average experience of senior employees to the reference level used in the learning curve.

Average Rookie Quality by Department[vendor,department]=ZIDZ ( Rookie Employees Quality[vendor,department] , Rookie Employees[vendor,department] )

- ~ quality
- Avg quality of rookies

Average Senior Quality by Department[vendor,department]=ZIDZ ( Experienced Employees Quality[vendor,department] , Experienced Employees[vendor,department] )

- ~ quality
- Average quality of experienced people.

Experienced Employees[vendor,department] = INTEG ( Assimilation Rate[vendor,department] - Experienced Layoff Rate[vendor,department] - Experienced Quit Rate[vendor,department] , Initial Experienced Employees[vendor,department] )

- ~ People
- Number of experienced employees equals assimilation rate minus experienced layoff rate and experienced quit rate.


- ~ Persons
- Number of rookie employees equals rookie hire rate minus rookie quit rate, rookie layoff rate and assimilation rate to become experienced employees.

~ Person*Hours/Year
~ Total effective person hours of effort available from experienced employees equals the actual work effort net of administrative work multiplied by the total productivity effect.

Effect of Senior Employee Experience on Productivity[vendor, department] = MIN [ { Relative Senior Experience[vendor, department] } ^ Employee Experience Curve Strength[vendor, department] , Max Employee Productivity from Experience]

~ Dimensionless
~ Learning curve for productivity from experience (from Sterman pg 507, from Zangwill and Kantor (1998)). Productivity will never rise above some maximum no matter how high relative experience rises.

Average Rookie Experience[vendor, department] = ZIDZ(Rookie Employees Experience[vendor, department], Rookie Employees[vendor, department])

~ Hours
~ Average rookies' work experience (in hours).

Effect of Experienced Employee Quality on Productivity[vendor, department] = 1 + Sensitivity of Employee Quality Effect * (Function for Effect of Employee Quality on Productivity(Average Senior Quality by Department[vendor, department]/Reference Quality)-1)

~ Dimensionless
~ Effect of experienced people's quality on productivity.

Effect of Rookie Employee Quality on Productivity[vendor, department] = 1 + Sensitivity of Employee Quality Effect * (Function for Effect of Employee Quality on Productivity(Average Rookie Quality by Department[vendor, department]/Reference Quality)-1)

~ Dimensionless
~ Effect of rookie quality on productivity.

Sensitivity of Employee Quality Effect = 1

~ Dimensionless [0, 2, 0.1]
~ Used to convert quality unit into dimensionless unit of productivity effect.

Experienced Work Effort for Non Administrative Work[vendor, department] = MAX(0, Experienced Work Effort Net of Grantseeking VC Financing and Coaching[vendor, department] - Participation Managing Effort[vendor, department] - Senior Participation Effort[vendor, department])

~ Hours*Person/Year
~ Experienced work effort for non administrative work (sales and product development) after subtracting participation efforts and coaching effort for participation.


~ Person*Hours/Year
~ Experienced work effort available for product development and sales after efforts for coaching, grantseeking, and VC financing.

Net Required Coaching Effort[vendor, department] = Net Time Spent Coaching * Experienced Employee Time Spent Coaching Rookies[vendor, department]

~ Hours*Person/Year
~ The net required coaching effort is total coaching effort reduced by the extent to which productive work can be accomplished while coaching or being coached.

Rookie Effective Work Effort[vendor, department] = (Rookie Work Effort[vendor, department] - Rookie Participation Effort[vendor, department]) * Total Rookie Productivity Effect[vendor, department]

~ Person*Hours/Year
Total effective person hours of effort available from rookie employees equals the actual work effort net of participation effort multiplied by the total productivity effect.

Customer Payback Period

Carbon Tax Phase In End Time = Carbon Tax Start Time + Carbon Tax Phase In Time

\[ CT1 = \frac{\text{Carbon Tax Increase Rate} \times \text{Discount Rate for Energy Costs} \times (\text{exp}(-\text{Discount Rate for Energy Costs} \times (\text{Carbon Tax Start Time} - \text{Time})) - \text{exp}(-\text{Discount Rate for Energy Costs} \times (\text{Carbon Tax Phase In End Time} - \text{Time}))))}{\text{Discount Rate for Energy Costs}} \]

\[ CT2 = \frac{\text{Carbon Tax Increase Rate} \times \text{Discount Rate for Energy Costs} \times (\text{Carbon Tax Start Time} - \text{Time} - \frac{\text{exp}(-\text{Discount Rate for Energy Costs} \times (\text{Carbon Tax Phase In End Time} - \text{Time})))}{\text{Discount Rate for Energy Costs}} + \frac{1}{\text{Discount Rate for Energy Costs}})}{\text{Discount Rate for Energy Costs}} \]

\[ CT3 = \text{Final Carbon Tax per kWh} \times \text{Discount Rate for Energy Costs} \]

Discount Rate for Energy Costs = 0.04 Year


\[ \text{Energy Cost Savings as Percentage of Incumbent[vendor]} = \frac{\text{Energy Cost Savings[vendor]}}{\text{Energy Costs[incumbent]}} \times 100 \]

Final Carbon Tax = 50 $/tons

Fractional Percentage Growth Rate of Energy Price = 5 1/Year

Infinity = 10000 Year

NPV of Carbon Tax[vendor] = IF THEN ELSE(Time < Carbon Tax Start Time, CT1, IF THEN ELSE(Time > Carbon Tax Phase In End Time, CT3, CT2)) \times Energy Use[vendor] \times (\frac{\text{Energy Cost Savings as Percentage of Incumbent[vendor]}}{100})


NPV of Energy Savings without Carbon Tax[vendor] = Energy Use[vendor] \times (\frac{\text{Energy Cost Savings as Percentage of Incumbent[vendor]}}{100}) \times (\text{Energy Price}/(\text{Discount Rate for Energy Costs} - \text{Fractional Percentage Growth Rate of Energy Price}))

NPV of Maintenance Costs[vendor] = Annual Service Fee per Unit[vendor] \times \text{Discount Rate for Energy Costs}
   ~ $/Unit

   ~ $/Unit

Switch for Carbon Tax=1
   ~ Dimensionless \([0,1,1]\)

Carbon Tax Start Time=21
   ~ Year \([0,?]\)
   ~ Time at which carbon policy starts having an effect

Energy Price=Initial Energy Price*exp(Fractional Percentage Growth Rate of Energy Price/100*Time)+Carbon Tax
   ~ $/kWh
   ~ Energy price grows at the fractional growth rate, plus the carbon tax.

Energy Use[vendor] = Initial Energy Use * Effect of Functionality on Energy Use[vendor]
   ~ kWh/Year/Unit

Initial Energy Use=180000
   ~ kWh/Year/Unit
   ~ Choice (1) $170,000 comes from $16,000 traditional HVAC energy cost per year / $0.83 energy price (combination of electricity and gas). Choice (2) $700,000 = 50,000 sq foot * 14 kw/sq foot. Calibrated based on 7Solar’s target market segment data.

Bankrupt Time=SAMPLE IF TRUE( NOT: Bankrupt Time :AND: Bankruptcy Switch[startup1] = 1, Time, 0)
   ~ Year
   ~ Use SAMPLE IF TRUE to retain the time when company goes bankrupt.

Cash[vendor]=MAX(0,Working Capital[vendor])
   ~ $

Initial Investment[startup1]=1e+006
Initial Investment[nonstartup1]=0
   ~ $ [0,1e+007,500000]
   ~ Assuming firm starts with $1m including angel investing.

Average Financing Period for New Sales = 4
   ~ years
   ~ Average years of financing for paying new sales.

Balance Sheet Error[vendor] = ZIDZ (( Total Assets[vendor] - Total Liabilities and Equity[vendor]) , Total Assets[vendor])
   ~ Dimensionless
   ~ This is a control variable that tests the basic accounting rule that total assets must equal total liabilities plus equity. Returns the error as a fraction of total assets. Zero if assets are zero.

Balance Sheet percent error[vendor] = 100 * ZIDZ ( Balance Sheet Error[vendor] , Total Assets[vendor] )
   ~ Dimensionless/$
   ~ Balance sheet error as percentage of total assets.

Bankruptcy Threshold[vendor]=0
   ~ $
   ~ The tolerable amount of arrears before company forced into bankruptcy.

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\[ \text{Downpayment Fraction} = 1 \text{ Dimensionless} \]
\[ \text{Revenue from New Sales} \]
\[ \text{Billings of downpayment from new sales.} \]

Cash Coverage[vendor] = \( \frac{ZIDZ}{\text{Working Capital[vendor] + Cash Out[vendor]}} \)

\[ \text{Year} \]
\[ \text{Year} \]
\[ \text{Cash received is the sum of sales revenue and the proceeds from the sale of shares to the public.} \]


\[ \text{Year} \]
\[ \text{Year} \]
\[ \text{Total cash received is the sum of sales revenue and the proceeds from the sale of shares to the public.} \]

Cash Out[vendor] = Required Payments[vendor]

\[ \text{Year} \]
\[ \text{Year} \]
\[ \text{The firm makes payments at the required rate or the maximum rate it can based on its cash balance, whichever is less.} \]

Current Liabilities[vendor] = Accounts Payable[vendor]

\[ \text{} \]
\[ \text{The current liabilities are equal to the account payable as the model does not include long term debt.} \]


\[ \text{Dollars/Year} \]
\[ \text{Customer billings as the sum of billing for downpayment, time payment due for new sales and revenue from service fee.} \]

Default Rate[vendor] = Normal Default Fraction[vendor] * Effect of Cust Support on Default Rate Fn (Customer Service Quality[vendor])

\[ \text{1/years} \]
\[ \text{Rate at which customers are defaulting based on our cust support and their financial condition} \]

Downpayment Fraction[vendor] = 1

\[ \text{Dimensionless} \]
\[ \text{The fraction of revenue from new sales as downpayment. 1 means full payment at the point of purchase.} \]

Effect of Cust Support on Default Rate Fn ([(0,0)-(5,20),(0.05,20),(0.1,5),(0.2,3.25),(0.5,2),(0.7,1.3),(1,1),(5,0.5),(100,0.25)])

\[ \text{Dimensionless} \]
\[ \text{With no customer support at all, all customers default, with norm cust support, defaults are normal, and with maximum cust support, curve is asymptotic to one quarter the default rate} \]

Follow on Funding[vendor] = Payments Received from Grants[vendor]

\[ \text{Year} \]


\[ \text{Year} \]
\[ \text{All expenses accumulate in accounts payable until they are paid.} \]

Increase in Receivables for New Sales[vendor] = (1 - Downpayment Fraction[vendor]) * Revenue from New Sales[vendor]

\[ \text{Year} \]
\[ \text{Revenue from new sales not yet receivable after downpayment.} \]
Increase in Retained Earnings = Net Income - Net of Profit Sharing + Proceeds from Sale of Assets + Depreciation

\[ \text{\$/Year} \]

This formula calculates the Retained Earnings coming from both operations and fundraising.

Initial Funding = \( \text{PULSE} \left( \text{Startup Date}, 0 \right) \times \frac{\text{Non Startup Initial Investment}}{\text{TIME STEP}} \)

\[ \text{\$/Year} \]

The initial funding represents the amount of cash made available to the company at its start date. It is modeled as an explicit inflow instead of an initial value of the cash stock in order to allow different startup dates.

Maximum Payments from Cash on Hand = Working Capital / Minimum Cash Disbursement Time

\[ \text{\$/Year} \]

The maximum rate at which the firm will make payments, based on the cash balance and the fastest time period over which the firm can make payments.

Minimum Cash Disbursement Time = \( \text{TIME STEP} \)

\[ \text{Year} \]

The firm can pay out all its remaining cash in one time step (that is, the actual disbursement time is very small relative to the time step).

Net Change in Accounts Payable = Increase in Accounts Payable - Payment of Accounts Payable

\[ \text{\$/Year} \]

This variable measures the net change in Accounts payable by comparing the inflow and the outflow.

Normal Default Fraction = 0

\[ 1/\text{Year} \]

The 'normal' fraction of customers that default on what they owe per year.

Normal Payment Time = 0.125 years

\[ \text{years} \]

This parameter measures the normal time until accounts payable are settled.

Payment of Accounts Payable = Cash Out

\[ \text{\$/Year} \]

Accounts payable fall with the actual payments made by the firm.

Payment Shortage = Required Payments - Payments for Operating Expense

\[ \text{\$/Year} \]

Sale of Equity = Initial Funding + Follow on Funding + Proceeds from Sale of Equity

\[ \text{\$/Year} \]

The Inflow to the Sale of equity is determined by the initial funding and other money raised.

Simulation Time Horizon = 15 years

\[ \text{The normal length of the simulation} \]

Switch for Bankruptcy[startup1] = 1
Switch for Bankruptcy[startup2] = 0
Switch for Bankruptcy[incumbent] = 0

\[ \text{Dimensionless [0,1,1]} \]

~ $/Year
~ Time payments due for new sales after downpayment.

Accounts Payable[vendor] = INTEG( Increase in Accounts Payable[vendor] - Payment of Accounts Payable[vendor] , 0)

~ $
~ This stock keeps track of accounts payable. In this model, accounts payable are paid consistently based on the normal payment time. There is no liquidity management.

Cumulative Retained Earnings[vendor] = INTEG( Increase in Retained Earnings[vendor], 0)

~ $
~ Cumulative retained earnings increases with current retained earnings, which are determined by net income and various other charges and sources of funds.

Equity[vendor] = Cumulative Retained Earnings[vendor] + Paid in Capital[vendor]

~ $
~ This variable tracks total equity as part of the simulated balance sheet.

Paid in Capital[vendor] = INTEG( Sale of Equity[vendor], Initial Investment[vendor] )

~ $
~ This variable tracks paid in capital raised through sale of equity.


~ $
~ This accounting formula measures Total assets.


~ $
~ Total current assets are cash and value of the inventory (Note that there are no accounts receivable as all receivables are assumed to be received instantly).

Total Liabilities and Equity[vendor] = Equity[vendor] + Total Liabilities[vendor]

~ $
~ This measures total liabilities plus equity.

Avg Receivable Delay = 0.125
~ Year [0.1,12,0.1]
~ How long it takes on average to get paid

Bankruptcy Switch[vendor] = Switch for Bankruptcy[vendor] * IF THEN ELSE ( Working Capital[vendor] < Bankruptcy Threshold[vendor], 1, 0)

~ Dimensionless [0,1,1]
~ Bankruptcy switch is on when payment shortage exceeds the tolerable threshold.

Incumbent Startup Date=1000
~ Year [0,21,1]

Non Startup1 Initial Investment[startup1]=0
Non Startup1 Initial Investment[nonstartup1]=3e+006
~ $ [0,1e+007,1e+006]
~ The amount of cash available for the company at its simulated start date.

Startup2 Start Date=1000
~ Year [0,21,1]


~ $
Revenue waiting to be received in cash

Cash Flow

Adjustment to Financing for Cash[vendor] = MAX(0, (Target Cash on Hand[vendor] - Working Capital[vendor]) / Time to Adjust Cash)

$/Year

The firm seeks to adjust its cash balance to the target level of the Time to Adjust Cash.


$/Year

Cash flow equals to the sum of cash flows from operations, investing and financing.

Cash Flow from Investing[vendor] = Proceeds from Sale of Assets[vendor] - Proceeds from Acquisition of Assets

$/Year

Desired Cash Coverage[vendor] = 0.167

Year [0,3,0.1]

The fraction of a year of expected expenditures the firm desires to have in cash.

Payments for Operating Expense[vendor] = MIN ( Maximum Payments from Cash on Hand[vendor] , Required Payments[vendor] )

$/Year

Actual payment made for operating expense is the lesser of the maximum payments from cash on hand and the required payments at normal payment time.

Proceeds from Acquisition of Assets = 0

$/Year

Proceeds from Acquisition of Equity[vendor] = 0

$/Year

Proceeds from Employee Options[vendor] = SUM ( Total Basis of Options Exercised[vendor,department] )

$/Year

The cash proceeds received by the firm from employees exercising their options is the total, across all departments, of the amount paid in by employees for the strike price of the options they exercise.

Proceeds from IPO[vendor] = IPO Shares[vendor] * Stock Price[vendor]

$/Year

Total funds raised by the IPO depends on the number of shares sold in the initial offering and the stock price at issue.

Proceeds from Sale of Assets[vendor] = 0

$/Year

Proceeds from Shares Sold to Public[vendor] = New Shares Issued to Public[vendor] * Stock Price[vendor]

$/Year

Total funds raised by secondary stock sales to the public depend on the number of shares issued and the stock price at issue.

Proceeds from VC financing[vendor] = Funds Raised From VCs[vendor]

$/Year

Required Payments[vendor] = Accounts Payable[vendor] / Normal Payment Time

$/Year

The firm seeks to pay accounts payable in the normal payment time.
Target Cash on Hand[vendor] = Desired Cash Coverage[vendor] * Required Payments[vendor]
~ $  
~ The firm seeks to maintain cash sufficient to provide a certain coverage of its required expenditures.

Time to Adjust Cash = 0.125 years  
~ The time over which the firm seeks to bring its cash balance in line with the target level.

Proceeds from Sale of Equity[vendor] = Proceeds from IPO[vendor] + Proceeds from VC financing[vendor] + Proceeds from Shares Sold to Public[vendor] + Proceeds from Employee Options[vendor]
~ $/Year  
~ The rate at which money is raised by sale of equity depends on the value of shares sold in the IPO, to VCs, plus the value of any shares sold in secondary offerings, and the funds received from the proceeds from options exercised by employees (the strike price multiplied by the number of options exercised by employees).

~ Dollars/Year  
~ Amount of cash coming in from customers

Years of Runway[vendor] = ZIDZ (Working Capital[vendor], Burn Rate[vendor])
~ Year  
~ If we’re burning cash, then years of cash we have left. If positive cash flow, burn rate is zero, then runway is zero.

Desired Engineers

Desired Engineers[vendor]= GAME (Desired Engineering Effort[vendor] / Normal Work Hours per Year)
~ People  
~ How many Engineers we need to make up the feature shortfall, based on their productivity and how many hours are needed for cust support (current engineering) (but can't be negative if too many features)

Desired Feature Development Rate[vendor,featuretype] = MAX ( 0, Desired Feature Completion Rate[vendor,featuretype] + Adjustment for Feature Under Development[vendor,featuretype] )
~ Features/Year  
~ At what rate do we want to be starting feature development, taking into account the features already under development.

Engineer Hours Required per Feature[featuretype]=100, 1000
~ Person*Hours/Feature  
~ How many hours it would take one engineer to develop a feature

~ Dimensionless

Effect of Payback Period on Desired Sales Force[vendor]=Function for Effect of Payback Period on Desired Sales Force[Payback Period[vendor]/Maximum Payback Period for Customer Consideration]
~ Dimensionless
Function for Effect of Customer Service Shortage on Desired Sales Force:

\[ (0,0)-(1,1),(0,1),(0.15,0.6),(0.35,0.3),(0.65,0.08),(1,0) \]

- Higher customer service shortage fraction, less desired sales force since customer service has priority over new customers.

Function for Effect of Payback Period on Desired Sales Force:

\[ (0,0)-(1,1),(0,1),(0.5,1),(0.6,0.8),(0.7,0.5),(0.8,0.2),(0.9,0.05),(1,0) \]

- Before the payback period reaches 7 years, the firm focuses on product development not sales, thus the desired sales force is constrained the longer the payback period.

Sensitivity of Customer Service Priority = 0.5

Desired Sales Effort for Hot Prospects:

\[ \text{Weighted total prospects}[\text{vendor}] \times \text{Fractional Sales Effort for Hot Prospects}[\text{vendor}], \text{Sales Productivity}[\text{vendor}] \] / Person*Hours/Year

Desired sales effort for prospects is the normal prospect generation rate divided by the sales productivity for that prospects.

Desired Sales Effort for Poaching:

\[ \text{Weighted total prospects}[\text{vendor}] \times \text{Fractional Sales Effort for Poaching}[\text{vendor}], \text{Sales Productivity}[\text{vendor}] \] / Person*Hours/Year

Desired sales effort for prospects is the normal prospect generation rate divided by the sales productivity for that prospects.

Desired Sales Effort for Potential Customers:

\[ \text{Weighted total prospects}[\text{vendor}] \times \text{Fractional Sales Effort for Potential Customers}[\text{vendor}], \text{Sales Productivity}[\text{vendor}] \] / Person*Hours/Year

Desired sales effort for prospects is the normal prospect generation rate divided by the sales productivity for that prospects.

Desired Sales Effort for Potential Prospects:

\[ \text{Weighted total prospects}[\text{vendor}] \times \text{Fractional Sales Effort for Potential Prospects}[\text{vendor}], \text{Sales Productivity}[\text{vendor}] \] / Person*Hours/Year

Desired sales effort for prospects is the normal prospect generation rate divided by the sales productivity for that prospects.

Desired Sales Effort for Prospects:

\[ \text{Weighted total prospects}[\text{vendor}] \times \text{Fractional Sales Effort for Prospects}[\text{vendor}], \text{Sales Productivity}[\text{vendor}] \] / Person*Hours/Year

Desired sales effort for prospects is the normal prospect generation rate divided by the sales productivity for that prospects.

Desired Sales Force:

\[ \text{GAME} (\text{Desired Sales Effort}[\text{vendor}] / \text{Normal Work Hours per Year} \times \text{Effect of Payback Period on Desired Sales Force}[\text{vendor}] \times \text{Effect of Customer Service Shortage on Desired Sales Force}[\text{vendor}]) / \text{People} \]

The number of sales people needed given the total person-hours of effort needed and the number of hours worked per year.

Normal Adopter Generation Rate:

\[ \text{MAX}(0, \text{Hot Prospects}[\text{Firm}]) / \text{Normal Adopter Generation Time} \]

Rate at which prospects can be persuaded to trial the product.

Normal Hot Prospect Generation Rate:

\[ \text{Prospects}[\text{Firm}] / \text{Normal Hot Prospect Generation Time} \]

Rate at which prospects can be persuaded to trial the product.

Normal Poaching Rate:

\[ \text{Adopters}[\text{customer}] / \text{Normal Poach Time} \]
Prospects/Year
Rate at which prospects can be persuaded to trial the product

~ Prospects/Year
~ Rate at which prospects can be persuaded to trial the product

Normal Potential Prospect Generation Rate = Potential Customers / Normal Potential Prospect Generation Time
~ Prospects/Year
~ Rate at which prospects can be persuaded to trial the product

Potential Customers Emphasis Multiplier[Firm]=0.05
~ Dimensionless
~ Since the number of total potential customers is huge, firm allocates little weight to them as opposed to other prospects in the chain.

Hot Prospect Emphasis Multiplier[Firm]=0.3
~ Dmnl
~ Emphasis sales force places on hot prospects

Poaching Emphasis Multiplier[Firm]= 0.1
~ Dmnl
~ Emphasis sales force places on purchasers (since they already purchased, relatively less emphasis)

Potential Prospects Emphasis Multiplier[Firm]=0.1
~ Dimensionless

Prospect Emphasis Multiplier[Firm]=0.2
~ Dmnl
~ Emphasis sales force places on prospects

Total Normal Hot Prospect Generation Rate = SUM ( Normal Hot Prospect Generation Rate[Firm] )
~ Prospects/Year

Total Normal Poaching Rate = SUM ( Normal Poaching Rate[customer] )
~ Prospects/Year

Total Normal Prospect Generation Rate = SUM ( Normal Prospect Generation Rate[Firm] )
~ Prospects/Year
~ The total rate at which potential prospects might be converted to prospects, over all firms.

Total Normal Purchase Rate = SUM ( Normal Adopter Generation Rate[Firm] )
~ Prospects

~ Prospects/Year
~ Number of prospects weighted by relative importance of prospects vs. hot prospects vs. purchasers for the purpose of applying sales effort

Energy Prices and Carbon Policy

CO2 Emission per kWh=0.000606
~ tons/kWh
~ US average value in 1998-2000. or 1.34 pounds/kWh see www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html
Final Carbon Tax per kWh = Final Carbon Tax \times CO2 Emission per kWh \times \text{Switch for Carbon Tax} \\
\sim \ $/kWh

Initial Energy Price = 0.083 \\
\sim \ $/kWh \\
\sim \ 2/3 \times 0.05/kw \ (\text{gas}) + 1/3 \times 0.15/kw \ (\text{electricity})

Carbon Tax = \text{RAMP} (\text{Carbon Tax Increase Rate, Carbon Tax Start Time, Carbon Tax Phase In End Time}) \\
\sim \ $/kWh \\
\sim \ \text{If there's a carbon tax, then it will ramp up to its final carbon tax}
\text{starting at start time and taking the amount of time specified by ramp time.}

Carbon Tax Increase Rate = \text{Final Carbon Tax per kWh}/\text{Carbon Tax Phase In Time} \\
\sim \ $/kWh/\text{Year} [0, 1, 0.01] \\
\sim \ \text{What fraction initial competitor cost will change based on carbon policy}
\text{(0.1 = 10\% increase, 1 = double, -1 means it goes to 0)}

Carbon Tax Phase In Time = 5 \\
\sim \ \text{Year} [0, ?] \\
\sim \ \text{Time it takes for carbon policy to take full effect}

********************************************************
Features Under Development
********************************************************

\text{Feasible Feature Development Rate} [\text{startup,featuretype}] = \text{Product Development Effort} [\text{startup,featuretype}] / \text{Engineer Hours Required per Feature}[\text{featuretype}] \\
\text{Feasible Feature Development Rate} [\text{incumbent,featuretype}] = 100000 Features/Year \\
\sim \ \text{Features/Year} \\
\sim \ \text{Given the engineering resources we have, and the amount of time it takes}
\text{to develop a feature, how many features can we develop per month}

\text{Feature Completion Rate 1}[\text{vendor,featuretype}] = \text{MIN} (\text{Features Under Development 1}[\text{vendor,featuretype}] / (\text{Average Feature Development Time}[\text{vendor}] / 3), \text{Feasible Feature Development Rate}[\text{vendor,featuretype}]) \\
\sim \ \text{Features/Year} \\
\sim \ \text{The rate at which features are developed into the product determined by}
\text{how many features were started and providing a 3rd order delay to complete}
\text{them in the avg feature devl time}

\text{Feature Completion Rate 2}[\text{vendor,featuretype}] = \text{MIN} (\text{Features Under Development 2}[\text{vendor,featuretype}] / \text{Average Feature Development Time}[\text{vendor}] / 3, \text{Feasible Feature Development Rate}[\text{vendor,featuretype}]) \\
\sim \ \text{Features/Year} \\
\sim \ \text{The rate at which features are developed into the product determined by}
\text{how many features were started and providing a 3rd order delay to complete}
\text{them in the avg feature devl time}

\text{Feature Completion Rate 3}[\text{vendor,featuretype}] = \text{MIN} (\text{Features Under Development 3}[\text{vendor,featuretype}] / \text{Average Feature Development Time}[\text{vendor}] / 3, \text{Feasible Feature Development Rate}[\text{vendor,featuretype}]) \\
\sim \ \text{Features/Year} \\
\sim \ \text{The rate at which features are developed into the product determined by}
\text{how many features were started and providing a 3rd order delay to complete}
\text{them in the avg feature devl time}

\text{Feature Start Rate}[\text{startup1,featuretype}] = \text{Switch for Game} \times \text{Feasible Feature Development Rate}[\text{startup1,featuretype}]
\sim \ (1 - \text{Switch for Game}) \times \text{MIN} (\text{Feasible Feature Development Rate}[\text{startup1,featuretype}], \text{Desired Feature Development Rate}[\text{startup1,featuretype}])

\text{Feature Start Rate}[\text{startup2,featuretype}] = \text{MIN} (\text{Feasible Feature Development Rate}[\text{startup2,featuretype}], \text{Desired Feature Development Rate}[\text{startup2,featuretype}])
\text{Feature Start Rate}[\text{incumbent,featuretype}] = \text{MIN} (\text{Feasible Feature Development Rate}[\text{incumbent,featuretype}], \text{Desired Feature Development Rate}[\text{incumbent,featuretype}])
Features/Year

Start features at the rate at which we can develop them. When Switch for game is on, feature start rate depends on product development effort and not constrained by desired feature development rate. Players can adjust the feature development by adjusting the number of engineers.

Features Under Development 1[vendor,featuretype] = INTEG( Feature Start Rate[vendor,featuretype] - Feature Completion Rate 1[vendor,featuretype] , 0)

~ Features
~ 1st stage of feature development

Features Under Development 2[vendor,featuretype] = INTEG( Feature Completion Rate 1[vendor,featuretype] - Feature Completion Rate 2[vendor,featuretype] , 0)

~ Features
~ 2nd stage of feature development

Features Under Development 3[vendor,featuretype] = INTEG( Feature Completion Rate 2[vendor,featuretype] - Feature Completion Rate 3[vendor,featuretype] , 0)

~ Features
~ 3rd stage of feature development

Average Feature Development Time[vendor]=1

~ Year [0.2,2,0.1]
~ How long, on average, does it take to develop a feature, regardless of how many engineers are working on it

*************************************************** *****

Financial Markets
*************************************************** *****

Base for Growth Rate Calculation = 1e+006

~ $/Year
~ The minimum base revenue rate used to estimate sales growth when the firm is very small.

Breakup Value[vendor] = MAX ( 0, Working Capital[vendor] - Total Liabilities[vendor])

~ $
~ The minimum value of the firm is its breakup or liquidation value, given by its cash, plus a fraction of its nonliquid assets, less its liabilities. The Salvage Value Ratio is typically < 1 because the firm will realize less than book value for its assets if forced to liquidate them. Breakup value is not less than zero.

Effective Sales Revenue for Expected Growth[vendor] = MAX ( Base for Growth Rate Calculation, Revenue[vendor] )

~ $/Year
~ The fractional growth rate for startups is close to infinite since the base is so small. Investors and managers do not expect such rates to continue; instead their estimates of growth tend to be based on a minimum revenue level.

Expected Growth in Revenue[vendor] = SMOOTH { Indicated Growth in Revenue[vendor], Time to Adjust Sales Growth Expectations, Initial Expected Revenue Growth[vendor]}

~ 1/Year
~ The expected fractional growth rate in sales revenue adjusts exponentially to the indicated rate.


~ $/Year
~ The expected profit of the firm used to value the firm is a weighted average of current profit and the expected steady state profit the firm is expected to achieve. The weight on actual net income is low during the startup honeymoon period, when investors are willing to tolerate losses while the firm invests in growth (through high expenditures and low
prices). After the startup honeymoon, however, investors revert to traditional valuation measures based on the actual profitability of the firm.

\[
\text{Expected Steady State Net Income} = \text{Expected Long Run Return on Sales} \times \text{Recent Sales Revenue for Growth Rate}
\]
\[
\sim \text{$/Year}
\]
\[
\sim \text{Investors expect the profits of the firm, over the long haul, to be a certain fraction of recent sales revenue.}
\]

Financial Results Reporting Time = 0.25 Year
\[
\sim \text{The time required for the firm to report financial results.}
\]

Historic Horizon for Sales Growth = 2 Year
\[
\sim \text{The historic horizon for the estimation of future growth in revenue.}
\]

Historic Sales Revenue = \text{SMOOTH} ( \text{Recent Sales Revenue for Growth Rate}, \text{Historic Horizon for Sales Growth}, \text{Recent Sales Revenue for Growth Rate} / (1 + \text{Initial Expected Revenue Growth} \times \text{Historic Horizon for Sales Growth}) )
\sim \text{$/Year}
\[
\sim \text{The historic sales rate used to estimate future growth is formed by exponential smoothing of recent sales. Initialized in steady state at the initial expected growth rate. See Sterman (2000) Chapter 16.}
\]

Honeymoon Period End Date = \text{Startup Date} + \text{Honeymoon Period}
\sim \text{years}
\]

Honeymoon Period = 4 Year [3.5,4.5,0.05]
\[
\sim \text{The length of the honeymoon period during which investors ignore current losses and value the firm using an expected steady state return on sales.}
\]

Indicated Growth in Revenue = \text{ZIDZ} ( \text{Recent Sales Revenue for Growth Rate} - \text{Historic Sales Revenue} \times \text{Historic Horizon for Sales Growth})
\sim \text{1/Year}
\[
\sim \text{The indicated growth rate in revenue is the annualized fractional difference between recent and historic sales revenue. Set to zero if historic revenue is zero.}
\]

Indicated Industry Return on Sales = IF \text{Time} > \text{Honeymoon Period End Date}, \text{Industry Average Return on Sales}, \text{Initial Expected Return on Sales}
\sim \text{Dimensionless}
\[
\sim \text{The indicated value of industry return on sales, to which investors' expectations adjust. Set to the initial expectation until a sufficient time has passed for investors to compile data on and assess industry experience.}
\]

Industry Average Return on Sales = \text{SUM} ( \text{Market share} \times \text{Return on Sales})
\sim \text{Dimensionless}
\[
\sim \text{Industry average return on sales is the return on sales of each firm weighted by its market share.}
\]

Initial Expected Return on Sales = 0.15
\sim \text{Dimensionless [0.0,0.2,0.01]}
\[
\sim \text{The initial expectation of investors for steady state return on sales revenue.}
\]

Initial Expected Revenue Growth = 0
\sim \text{1/Year}
\[
\sim \text{The initial expectation for sales growth for the firm in the capital markets.}
\]

Pre IPO Discount = IF \text{Time} <= \text{IPO Date}, 0.75, 1
\sim \text{Dimensionless}
The stock valuation is discounted prior to an IPO as the stock is less liquid as an investment.

Recent Net Income\[vendor\] = SMOOTH ( Net Income Net of Profit Sharing[\vendor\], Financial Results Reporting Time)

~ $/Year
~ The financial results of the firm are reported with a delay.

Recent Sales Revenue for Growth Rate[\vendor\] = SMOOTHI ( Effective Sales Revenue for Expected Growth[\vendor\], Financial Results Reporting Time, Effective Sales Revenue for Expected Growth[\vendor\] / ( 1 + Initial Expected Revenue Growth[\vendor\] * Financial Results Reporting Time ) )

~ $/Year
~ Recent sales averages sales over a short period to filter out noise.Initialized in steady state at the initial expected growth rate. See Sterman (2000) Chapter 16. Effective sales revenue for expected growth is the greater of actual sales or a base that represents a minimum revenue level, so that expected growth rates remain reasonable when sales are very small (the growth rate on the first sale is infinite, but expectations will not rise to infinity).

Return on Sales[\vendor\] = ZIDZ ( Recent Net Income[\vendor\], Recent Sales Revenue for Growth Rate[\vendor\] )

~ Dimensionless
~ Net income as a fraction of sales revenue. Set to zero if recent sales revenue is zero.

Sensitivity of Valuation to Rapid Growth = 1.05

~ Dimensionless [0.9,1.2,0.01]
~ This parameter determines the responsiveness of the price/earnings multiple assigned by the capital markets is to the expected growth in revenue when the expected growth rate exceeds the discount rate.

Time to Adjust Expected Long Run Return on Sales = 3

~ years [3,5,0.5]
~ The time over which investor expectations for the long run steady state return on sales of the industry adjust to the indicated value based on actual experience.

Time to Adjust Sales Growth Expectations = 0.5

~ Year
~ It takes time for expectations of growth to adjust to the indicated value.

Total Market = SUM ( Revenue[\vendor\] )

~ $/Year
~ The total market is the sum of the revenues of all firms.

Valuation Weight Adjustment Time = 1

~ Year
~ The time period over which the weight on actual net income for valuation adjusts to the indicated value, once the startup honeymoon period ends.

Weight on Actual Net Income After Startup Honeymoon Period[\vendor\] = Step ( 1, Honeymoon Period End Date[\vendor\] )

~ Dimensionless
~ After the honeymoon period for startups ends, the financial markets will use actual net income in their assessment of the firms value. The actual weight adjusts gradually to this level.

Weight on Actual Net Income for Valuation[\vendor\] = SMOOTH3i ( Weight on Actual Net Income After Startup Honeymoon Period[\vendor\], Valuation Weight Adjustment Time , 0)

~ Dimensionless
~ The weight investors give to actual net income in their valuation of the firm. Adjusts with a delay of the specified order to the indicated value of 1 once the startup honeymoon period ends.

Market share[\vendor\] = ZIDZ ( Revenue[\vendor\], Total Market )
Market share is calculated by comparing the company’s sales revenue to total sales revenue in the industry.

Total Liabilities = Current Liabilities

This measures the total liabilities of the company. There is no long term debt in this model.

Company in Operation Switch = IF THEN ELSE (Time >= Startup Date AND Bankruptcy Switch=0)

This switch is used to decide whether a given company has already begun its operations. Prior to the start of operations the key flows for the company are zero.

Discount Rate = 0.12

The discount rate used to evaluate the present value of expected profits.

Working Capital = \text{INTEG} (\text{Cash In} - \text{Cash Out} + \text{Follow on Funding} + \text{Initial Funding}, \text{Initial Investment})

This stock tracks the amount of cash currently held by the company.

\text{Firm Attractiveness from Payback Period} = \text{Function for Firm Attractiveness from Payback Period}(\text{Payback Period}/\text{Maximum Payback Period for Customer Consideration})

\text{Firm Attractiveness from Customer Support} = \text{Function for Firm Attractiveness from Customer Support}(\text{Customer Service Quality})

\text{Incumbent Firm Attractiveness} = 0

Initial Market Share = (1 - Initial Market Share) / 2

Initial Market Share = (1 - Initial Market Share) / 2

Initial Market Share = 0.9

\text{Firm Attractiveness from Customer Support} = \text{Function for Firm Attractiveness from Customer Support}(\text{Customer Service Quality})
Higher the customer service quality, more attractive the product is.

\[
\text{Firm Attractiveness from Marketing Effort} = \begin{cases} 
\text{Sensitivity of Attractiveness to Marketing Effort} & \text{if } \text{Sensitivity of Attractiveness to Marketing Effort} > 0, \\
\text{Indicated Attractiveness from Marketing Effort} & \text{otherwise}.
\end{cases}
\]

\[
\text{Firm Attractiveness from WOM} = \begin{cases} 
\text{Sensitivity of Attractiveness to WOM} & \text{if } \text{Sensitivity of Attractiveness to WOM} > 0, \\
\text{Indicated Attractiveness from WOM} & \text{otherwise}.
\end{cases}
\]

\[
\text{Indicated Attractiveness from Marketing Effort} = \frac{\text{Maximum Attractiveness from Marketing Effort}}{1 + \exp(\text{Sensitivity of Attractiveness to Marketing Effort} \times (\text{Marketing Effort at Half Saturation} - \text{Marketing Effort Relevant to Consumers})) / \text{Reference Marketing Effort}}.
\]

\[
\text{Indicated Attractiveness from WOM} = \frac{\text{Maximum Attractiveness from WOM}}{1 + \exp(\text{Sensitivity of Attractiveness to WOM} \times (\text{WOM at Half Saturation} - \text{WOM Relevant to Consumers}) / \text{Reference WOM}}.
\]

\[
\text{Marketing Effort at Half Saturation} = \text{Reference Marketing Effort} \times (1 + \exp(\text{Sensitivity of Attractiveness to Marketing Effort} \times (\text{Maximum Attractiveness from Marketing Effort} - 1) / \text{Sensitivity of Attractiveness to Marketing Effort})).
\]

\[
\text{Marketing Effort Relevant to Consumers} = \text{Maximum Relevant Marketing Effort} \times \text{Billing for Marketing Spending} / (\text{Maximum Relevant Marketing Effort} + \text{Billing for Marketing Spending}).
\]

\[
\text{Maximum Attractiveness from Marketing Effort} = 10
\]

\[
\text{Maximum Attractiveness from WOM} = 1.2
\]
Maximum attractiveness from WOM. Key points: Half saturation levels (for Sensitivity = 1), in format (Max Attractiveness, Half Sat value): (1.5, .31), (2, 1), (3, 1.69), (4, 2.10), (5, 2.39), (10, 3.20), (20, 3.94),
(30, 4.37), (40, 4.66), (50, 4.89), (100, 5.60), (200, 6.29), (300, 6.70).

Maximum Relevant Marketing Effort = 1e+010
~ $/Year [0,6e+010]
~ The maximum level of brand equity relevant to consumers when evaluating the value of the product.

Maximum Relevant WOM = 1e+007
~ Prospects/Year [0,6e+010]
~ The maximum level of WOM relevant to consumers when evaluating the value of the product.

Reference Marketing Effort = 1e+006
~ $/Year
~ The reference level of brand equity used in evaluating attractiveness.

Reference WOM = 1000
~ Prospects/Year
~ The reference level of WOM used in evaluating attractiveness.

Sensitivity of Attractiveness to Marketing Effort= 0.5
~ Dimensionless [0,1,0.01]
~ The sensitivity of attractiveness to brand equity.

Sensitivity of Attractiveness to WOM= 0.5
~ Dimensionless [0,1,0.01]
~ The sensitivity of attractiveness to brand equity.

Switch to include initial market share in marketing effort relevant to consumers = 0
~ Dmnl
~ Solar sim has this (I believe the reason is to make initial calibration of order share match the initial market share)

Switch to include initial market share in WOM relevant to consumers = 0
~ Dimensionless
~ Solar sim has this (I believe the reason is to make initial calibration of order share match the initial market share)

Total Firm Attractiveness = SUM ( Firm Attractiveness[vendor] )
~ Dimensionless
~ Total firm attractiveness as the sum of all firm attractiveness.

WOM at Half Saturation = Reference WOM * ( 1 + ZIDZ ( LN ( Maximum Attractiveness from WOM - 1 ), Sensitivity of Attractiveness to WOM ) )
~ Prospects/Year
~ Value of WOM where the impact on attractiveness reaches half the saturation value. Determined by the other parameters governing the impact of WOM, particularly the maximum attractiveness.

WOM Relevant to Consumers[vendor]= ( Maximum Relevant WOM * Total WOM[vendor] ) / ( Maximum Relevant WOM + Total WOM[vendor] ) / ( Switch to include initial market share in WOM relevant to consumers * Initial Market Share[vendor] + 1 - Switch to include initial market share in WOM relevant to consumers )
~ Prospects/Year
~ The level of WOM relevant to consumers in the assessment of attractiveness is the lesser of actual WOM or maximum relevant WOM determined by consumer preferences. Instead of a minimum function, with a sharp discontinuity, a continuous function is used that gradually saturates at the maximum level.

Total WOM[Firm]=WOM Contact Frequency from Adopters * Total Prospects and Adopters by Firm[Firm]
Prospects/Year

~

The volume of WOM generated is the WOM generated by all installed base.

WOM Contact Frequency from Adopters = 3
~
1/Year
~
Rate of contact between adopters and potential prospects (relatively high)

='='

Income Statement

Consumer Price After Subsidy[vendor]=Price[vendor]*(1-Government Subsidy Percentage/100)
~
$/Unit

Salary as Fraction of Operating Expenses[vendor]=Salary Expense[vendor]/Operating Expenses[vendor]
~
Dimensionless

Annual Service Fee per Unit[vendor]=Consumer Price After Subsidy[vendor]* Annual Service Fee Relative to Price[vendor]*Switch for Customer Support
~
$/Unit/Year
~
Service fee per year after a product is purchased, calculated as a fraction of the purchase price.

Annual Service Fee Relative to Price[vendor]=0.05
~
1/Year [0,1,0.01]
~
Service fee per year as a fraction of purchase price.

Average Loss Carry Forward Period = 5
~
years
~
The average carry forward period for losses.

Carry Forward Loss[vendor] = MAX ( 0, - Taxable Income[vendor] )
~
$/Year
~
The firm can accumulate losses and use them to offset future profits in calculating taxable income.

Carry Forward Loss Applied to Current Tax Liability[vendor] = MIN ( Maximum Carry Forward Loss Applicable to Current Tax Liability[vendor], MAX (0, Taxable Income[vendor]) )
~
$/Year
~
The carry forward loss applied to offset current taxable income is the lesser of current taxable income or the total carry forward credit available.

Cumulative Carry Forward Losses[vendor] = INTEG( Carry Forward Loss[vendor] - Decrease in Carry Forward Losses[vendor] , 0)
~
$
~
The firm's cumulative losses carried forward to offset potential future profit; increased by the net loss, decreases as the carry forward is used or expires.

Cumulative Losses[vendor] = INTEG( Losses[vendor] , 0)
~
$

Cumulative Profit[vendor]= INTEG (Net Income Net of Profit Sharing[vendor],0)
~
$
~
Cumulative (undiscounted) net income.

Cumulative Startup Losses[vendor] = INTEG( Startup Losses[vendor] , 0)
~
$

Date of First Profit[vendor] = INTEG( Recording of Profitability Date[vendor] , 0)
~
Year

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Decrease in Carry Forward Losses = Expiration of Unused Carry Forward Losses + Carry Forward Loss Applied to Current Tax Liability

~ $/Year
~ Carry forward losses can be used or expire.

Defaults on AR = Accounts Receivable * Default Rate
~ Dollars/Year
~ Dollars per month we're losing due to customer defaults on their bills

Discount Factor = \[\exp \left( - \text{Discount Rate for NPV of Profit } \times \text{Time} \right) \]
~ Dimensionless
~ Profit is discounted at a user-defined rate.

Discount Rate for NPV of Profit = 0.04
~ 1/Year
~ The discount rate used to compute the NPV of firm profits.

"Economies of Scale for G&A" = 0.8
~ Dimensionless
~ Determines the strength of the scale economy effect for G&A expenses.

Effective Tax Rate = 0
~ Dimensionless
~ The effective corporate tax rate.

Expiration of Unused Carry Forward Losses = Cumulative Carry Forward Losses / Average Loss Carry Forward Period
~ $/Year
~ Carry forward losses expire after a specified time.

"Fixed G&A Expense" = 200000
~ $/Year
~ The fixed, minimum component of the firm's administrative and overhead expenses.

Gross Margin = \[Z \text{IDZ} \times \left( \text{Gross Profit, Revenue} \right) \]
~ Dimensionless

Losses = IF THEN ELSE ( Net Income Net of Profit Sharing < 0, Net Income Net of Profit Sharing, 0)
~ $/Year
~ Rate to track losses.

Maintenance COGS = Installed Base * Operating and Maintenance Costs
~ Dollars/Year
~ The costs for providing maintenance service.

Maintenance Margin = (Annual Service Fee per Unit - Operating and Maintenance Costs) / Annual Service Fee per Unit
~ Dimensionless
~ The fraction of the maintenance charge which is profit. Target value is 40%.

Maximum Carry Forward Loss Applicable to Current Tax Liability = Cumulative Carry Forward Losses / TIME STEP
~ $/Year
~ The maximum rate the firm can draw down its prior losses to offset current tax liabilities. The time constant is assumed to be very short, so is set to the simulation time step, allowing the entire carry forward loss to be used in one time step if needed.

Min Gross Margin = 0
~ Dimension [-1,1,0.05]
Minimum margin company will charge (can be negative if wish to sell below cost to gain initial sales)

NPV of Profit[vendor] = INTEGR( Present Value of Profit[vendor], 0)

$Present Value of Profit[vendor]= Net Income Net of Profit Sharing[vendor] * Discount Factor

$Present Value of Profit[vendor]= Net Income Net of Profit Sharing[vendor] * Discount Factor

Discount Factor

Product COGS[vendor] = Unit Cost[vendor] * Adopter Generation Rate[vendor] * Unit Purchased per Adopter

$Cost of goods sold for products sold

Profitability Shutoff[vendor] = IF THEN ELSE ( Date of First Profit[vendor] > 0, 0, 1)

Dimensionless

Recording of Profitability Date[vendor] = IF THEN ELSE ( Net Income Net of Profit Sharing[vendor] > 0, Time / TIME STEP, 0) * Profitability Shutoff[vendor]

Dimensionless

"Reference Volume for G&A Expenses" = 1.5e+007

$/Year


$/Year

This calculates all salary expenses and G&A of the company.

Startup Losses[vendor] = IF THEN ELSE ( Net Income Net of Profit Sharing[vendor] < 0, Net Income Net of Profit Sharing[vendor], 0) * Profitability Shutoff[vendor]

$/Year

Rate to track initial losses.

Taxable Income[vendor] = Net Income Before Tax[vendor]

$/Year

Taxable income is NIBT, that is, operating income less any extraordinary charges.

Taxable Income After Carry Forward Losses[vendor] = MAX ( 0, Taxable Income[vendor]) - Carry Forward Loss Applied to Current Tax Liability[vendor]

$/Year

Taxable income after carry forward losses are applied. Carry forward losses reduce taxable income.

"Unit G&A Expense"[vendor]=1000

$/Unit

The variable overhead and administrative cost per item sold.


$/Year

The variable component of administrative overhead depends on order volume.

Price[startup1]= GAME (Switch for Game * Price for Game + ( 1 - Switch for Game ) * Endogenous Price[startup1])

Price[startup2] = Endogenous Price[startup2]

Price[incumbent]=Incumbent Price

$/Unit

Price of startup1 can be set endogenously or by game player.

Operating and Maintenance Costs[vendor] = Initial Operating and Maintenance Costs * Effect of Functionality on Operating and Maintenance Costs[vendor]

$/Year/Unit
Adopter Generation Rate[vendor] = INTEGER(SUM(Firm Specific Adopter Generation Rate[Firm], vendor) + 0.5) ~ Prospects/Year


Unit Cost[vendor] = Initial Unit Cost[vendor] * Effect of Learning Curve on Unit Cost[vendor] * Cost Adjustment Fraction Due To Policy ~ Dollars/Unit ~ Cost to manufacture/produce/provide product to purchasers. IF THEN ELSE is used to prevent floating error when initial cumulative purchase = 0.

********************************************* ***********

Job Attractiveness

Expected Present Value of Salary[vendor,department] = (Experienced Salary[vendor,department] + Value of Company Mission to Employees[vendor,department]) / Discount Rate for Total Compensation[vendor] ~ $/Person ~ The present value of the employee’s salary, computed assuming employees will be paid the salary for the experienced workers, plus the intrinsic value of working for a green company, discounted at a specified rate. Used to determine the total present value of the employee compensation package, including salary and options.


Function for Job Attractiveness from Financial Compensation LOWER BOUND([[(0.5, -0.6)-(1.3, 0.08)], (0.5, 0.55852), (0.55, -0.53104), (0.6, -0.4973), (0.65, -0.457166), (0.7, -0.410772), (0.75, -0.358072), (0.8, -0.299068), (0.85, -0.233758), (0.9, -0.162144), (0.95, -0.0842245), (1.0), (1.05, 0.0234295), (1.1, 0.042659), (1.15, 0.0576885), (1.2, 0.068518), (1.25, 0.0751475), (1.3, 0.077577)]) ~ Dimensionless ~ Higher the compensation, higher job attractiveness. Estimated using NBER Shared Capitalism dataset of 38,000 samples.

:SUPPLEMENTARY

Function for Job Attractiveness from Financial Compensation UPPER BOUND([(0.5, -0.4)-(1.5, 0.4)], (0.65, 0.240765), (0.7, 0.238065), (0.75, -0.2248), (0.8, -0.20097), (0.85, -0.166575), (0.9, -0.121615), (0.95, -0.06609), (1.0), (1.05, 0.0363565), (1.1, 0.070413), (1.15, 0.102169), (1.2, 0.131626), (1.25, 0.158782), (1.3, 0.183639), (1.35, 0.206196), (1.4, 0.226452), (1.45, 0.244409), (1.5, 0.260065)]) ~ Dimensionless ~ Higher the compensation, higher job attractiveness. Estimated using NBER Shared Capitalism dataset of 38,000 samples.

Layoff Rate[vendor,department] = Rookie Layoff Rate[vendor,department] + Experienced Layoff Rate[vendor,department] ~ People/Year
Effective Work Effort[vendor, department] = Rookie Effective Work Effort[vendor, department] + Experienced Effective Work Effort[vendor, department] / Person*Hour/Year


Job attractiveness for existing employees comes from the relative financial compensation and the non-financial factors such as burnout. Additive instead of multiplicative form is used since the regression estimates from the NBER Shared Capitalism dataset is in additive form.

Participation Culture by Department[vendor, department] = Average Participation[vendor, department] / Average Participation Experience Needed for Participation Culture

Overall company participation culture indexed between 0 and 1. When hours of average participation reaches the maximum participation hours needed, the participation culture reaches 1.

Working Hours per Year[vendor, department] = Current Workweek[vendor, department] * Workweek per Year / Hours/Year

Number of working hours per year.

Profit Sharing Amount[vendor] = MAX(0, Net Income Before Profit Sharing[vendor] * Profit Sharing as Percentage of Net Income[vendor]/100) / $/Year

Profit sharing amount equals net income times profit sharing as percentage of net income, provided that net income is positive.

Profit Sharing as Percentage of Net Income[vendor] = GAME (0)

Perceived Liquidity[vendor] = xIDZ (Working Capital[vendor], Target Cash on Hand[vendor], 1)

Perceived liquidity is the ratio of cash on hand to target cash required to support the firm's expenditures. Neutral before operations begin. Note that we assume there is no significant delay or bias in the employee's perception of the firm's cash position (we assume transparency). This assumption could be relaxed by including delays or biases that would for example prevent employees from discovering that a firm was in financial difficulty, as at Enron and WorldCom.


Desired sales effort is the sum of desired sales efforts for all prospects in the prospect chain.

Experienced Salary[vendor, department] = Reference Total Compensation[department] * Salary as Percentage of Industry Average[vendor]/100 / $/(Year*People)

Desired Grantseeking Effort by Department[vendor, department] = Desired Grantseeking Effort[vendor] / 2 / Person*Hours/Year

Desired grantseeking effort is assumed to come from sales and engineer proportionally.
Indicated Work Pressure[vendor, department] = xIDZ (Desired Work Effort[vendor, department], Effective Work Effort[vendor, department], 10)

- Dimensionless
- The ratio of the staff required relative to the existing staff available. Drives the workweek.

Average Employee Shares Outstanding[vendor, department] = xIDZ((Employee Shares Outstanding from Exercised Options[vendor, department] + Employee Shares[vendor, department]), Total Employees per Department[vendor, department])

- shares/Person

Job Attractiveness from Financial Compensation[vendor, department] = Sensitivity of Job Attractiveness from Financial Compensation * Function for Job Attractiveness from Financial Compensation(Normalized Expected Present Value of Total Compensation[vendor, department])

- Dimensionless
- If Sensitivity = 0, the effect is switched off, then job attractiveness = 1. Used because indicated attractiveness does not = 1 when sensitivity = 0.

Effect of Job Attractiveness on Workweek[vendor, department] = 1 + Sensitivity of Job Attractiveness on Workweek * (Function of Effect of Job Attractiveness on Willingness to Work Hard(Job Attractiveness for Existing Employees[vendor, department]) - 1)

- Dimensionless
- This captures the moderating effect of job attractiveness (JA) on the effect of schedule pressure on workweek (ESPW). The higher the job attractiveness, the higher willingness to work hard, thus given the same schedule pressure, actual workweek increases.

Employee Ownership Stake Relative to Salary[vendor, department] = xIDZ(Value of Average Employee Shares Outstanding[vendor, department], Average Salary[vendor])

- Year
- Value of the accumulative employee shares relative to average salary (how many years of salary would it take to equal the current value of the average employee's shares). This measure is chosen because the survey data available from the NBER Shared Capitalism dataset.

Expected Present Value of Profit Sharing[vendor, department] = Expected Profit Sharing per Employee[vendor, department]/Discount Rate for Total Compensation[vendor]

- $/Person

Expected Profit Sharing per Employee[vendor, department] = SMOOTH(Profit Sharing per Employee[vendor, department], Time to Adjust Expected Profit Sharing, 0)

- $/(Person*Year)

Expected Present Value of Stock Grants[vendor, department] = Stock Granted per Existing Employee[vendor, department] * Expected Value of Non Vested Stock Grants[vendor, department]/Discount Rate for Total Compensation[vendor]

- $/Person

Expected Value of Stock Options Relative to Market Capitalization[vendor, department] = xIDZ(Expected Value of Non Vested Stock Options[vendor, department], Market Capitalization[vendor])

- 1/Person

Function for Job Attractiveness from Employee Ownership([[0,0],
(3,0.06), (0,0), (0.01, 0.011973), (0.05, 0.012837), (0.2, 0.015998), (0.4, 0.02002), (0.6, 0.023821), (0.8, 0.0274), (1, 0.030759), (1.2, 0.033896), (1.4, 0.036812), (1.6, 0.039508), (1.8, 0.041982), (2, 0.044235), (2.25, 0.0465789), (2.5, 0.0484211), (2.75, 0.0495), (3, 0.05))

- Dimensionless
- A sudden jump in psychological job attractiveness arises from any employee ownership stake. The psychological impact of employee ownership rises gradually and at a slightly diminishing rate as the average employee ownership stake becomes larger relative to the average annual salary.
Function for Job Attractiveness from Financial Compensation:

\[(\{(0, -1) - (2, 0.4)\}, (0, 0.07, -0.680702), (0.2, 0.478070), (0.35, -0.389474), (0.5, -0.371947), (0.55, -0.372714), (0.6, -0.365045), (0.65, -0.348941), (0.7, -0.3244, (0.75, -0.291423), (0.8, -0.250011), (0.85, -0.200162), (0.9, -0.141877), (0.95, -0.075157), (1, 0.05029893), (1.1, 0.056534), (1.15, 0.079923), (1.2, 0.100062), (1.25, 0.116949), (1.3, 0.130584), (1.35, 0.140968), (1.4, 0.148101), (1.6, 0.175), (2, 0.2), (3, 0.23))\]

~ Dimensionless
~ Higher the compensation, higher job attractiveness. Estimated using NBER Shared Capitalism dataset of 38,000 samples.

Function for Job Attractiveness from Financial Compensation 0:

\[(\{(0.5, -0.4) - (1.5, 0.4)\}, (0.5, 0.371947), (0.55, -0.372714), (0.6, -0.365045), (0.65, -0.348941), (0.7, -0.3244, (0.75, -0.291423), (0.8, -0.250011), (0.85, -0.200162), (0.9, -0.141877), (0.95, -0.075157), (1, 0.05029893), (1.1, 0.056534), (1.15, 0.079923), (1.2, 0.100062), (1.25, 0.116949), (1.3, 0.130584), (1.35, 0.140968), (1.4, 0.148101), (1.45, 0.151983), (1.5, 0.152613))\]

~ Dimensionless
~ Higher the compensation, higher job attractiveness. Estimated using NBER Shared Capitalism dataset of 38,000 samples.

Function for Job Attractiveness from Option Grants:

\[(\{(0, 0) - (1500, 0.1)\}, (0, 0), (0.5, 0.013373), (1, 0.013964), (2, 0.015138), (3, 0.016301), (4, 0.017452), (5, 0.018591), (6, 0.019719), (7, 0.020835), (8, 0.02194), (9, 0.023033), (10, 0.024115))\]

~ Dimensionless
~ Cumulative options less than 1 basis point lowers job attractiveness due to feeling of insult, increase positively once passes 1 basis point, saturate at the 1500 basis point as one possesses all 15% option pool.

Function for Job Attractiveness from Option Grants 0:

\[(\{(0, 0) - (10, 0.04)\}, (0, 0), (0.5, 0.013373), (1, 0.013964), (2, 0.015138), (3, 0.016301), (4, 0.017452), (5, 0.018591), (6, 0.019719), (7, 0.020835), (8, 0.02194), (9, 0.023033), (10, 0.024115))\]

~ Dimensionless
~ A sudden jump of psychological job attractiveness effect from having the first 1000 options, additional options increase job attractiveness at small rate, signaling psychological effect of option grants come more from having it or not as oppose to the quantity. The financial effect from the expected value of options is captured separately in the Job Attractiveness from Financial Compensation. This only capture the psychological effect of having the options regardless of their worth. Estimated using NBER Shared Capitalism dataset of 38,000 samples.

Function for Job Attractiveness from Participation:

\[(\{(0, 0) - (1.0, 0.1)\}, (0, 0), (0.3, 0.01), (0.43, 0.01), (0.55, 0.03), (0.65, 0.055), (0.75, 0.075), (0.88, 0.09), (1.0, 0.1))\]

~ Dimensionless
~ Higher the participatory culture (after a certain threshold), higher the job attractiveness.

Function for Job Attractiveness from Profit Sharing:

\[(\{(0, -0.004) - (60, 0.06)\}, (0, 0), (1, 0.00291), (5, 0.005877), (10, 0.01588), (15, 0.024792), (20, 0.032615), (25, 0.039348), (30, 0.04499), (35, 0.049543), (40, 0.053005), (45, 0.055377), (50, 0.05666), (55, 0.056582), (60, 0.055954))\]

~ Dimensionless
~ Estimated using NBER Shared Capitalism dataset of 38,000 samples. The initial drop of job attractiveness when given only 1% of profit sharing as % of salary can be interpreted as people resent the company being hypocritical by calling itself profit sharing when only giving 1%.

Function of Effect of Burnout on Job Attractiveness:

\[(\{(0.5, -0.08) - (1.8, 0.08)\}, (0.5, 0.032), (0.6, 0.03), (0.7, 0.025), (0.8, 0.018), (0.9, 0.011), (1.0, 0.012), (1.2, 0.027), (1.3, 0.04), (1.4, -0.052), (1.5, -0.065), (1.6, -0.065), (1.7, -0.068), (1.8, 0.07))\]

~ Dimensionless

Function of Effect of Job Attractiveness on Willingness to Work Hard:

\[(\{(1.0, -1.3) - (1.4, 0.1)\}, (1.0, 0.450211), (1.0, 0.468243), (1.2, 0.487608), (1.3, 0.508334), (1.4, 0.530437), (1.5, 0.553917), (1.6, 0.578753), (1.7, 0.604905), (1.8, 0.632309), (1.9, 0.660872), (2.0, 0.690476), (2.1, 0.720976), (2.2, 0.752198), (2.3, 0.783941), (2.4, 0.815981), (2.5, 0.848072), (2.6, 0.879954), (2.7, 0.91)

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The higher the job attractiveness, the higher the willingness to work hard. Estimated using NBER Shared Capitalism dataset of 38,000 samples.

Function of Effect of Layoff on Job Attractiveness $\{(0,-.2)-(1,0), (0,0), (0.05,-.003), (0.11,-.007), (0.17,-.014), (0.25,-.028), (0.35,-.043), (0.43,-.056), (0.53,-.072), (0.63,-.083), (0.78,-.093), (1,-.1)\}$

- Dimensionless
- The higher the perceived fraction of total employees in each department being laid off, the lower the job attractiveness in that department

Function of Reporting Time for Job Attractiveness $\{(0,0)-(2,0.6),(0,0.083),(1,0.25),(2,0.5)\}$

- Year
- As company expands and the number of employees grows, the longer it takes to survey and report job attractiveness, formally or informally.

Job Attractiveness for New Hires $\{\text{vendor,department}\} = \text{Job Attractiveness from Financial Compensation} \{\text{vendor,department}\} + \text{Perceived Non Financial Job Attractiveness} \{\text{vendor,department}\} + 3$

- Dimensionless
- Job attractiveness for new hires is driven by the financial compensation and the perceived job satisfaction. Addictive instead of multiplicative form is used to match the NBER Shared Capitalism dataset.

Job Attractiveness from Burnout $\{\text{vendor, department}\} = \text{Sensitivity of Burnout Effect} \times \text{Function of Effect of Burnout on Job Attractiveness} \{\text{Recent Average Workweek} / \text{Normal Workweek}\}$

- Dimensionless

Job Attractiveness from Employee Ownership Stake $\{\text{vendor, department}\} = \text{Sensitivity of Job Attractiveness from Employee Ownership} \times \text{Function for Job Attractiveness from Employee Ownership} \{\text{Employee Ownership Stake Relative to Salary} / \text{Reference Employee Ownership Stake Relative to Salary}\}$

- Dimensionless

Job Attractiveness from Layoff $\{\text{vendor, department}\} = \text{Sensitivity of Layoff Effect} \times \text{Function of Effect of Layoff on Job Attractiveness} \{\text{Perceived Layoff Fraction}\}$

- Dimensionless

Job Attractiveness from Option Grants $\{\text{vendor, department}\} = \text{Sensitivity of Job Attractiveness from Option Grants} \times \text{Function for Job Attractiveness from Option Grants} \{\text{Cumulative Options per Employee as Basis Point of Shares Outstanding} / \text{Minimum Basis Point of Cumulative Options for Positive Psychological Effect}\}$

- Dimensionless

Job Attractiveness from Participation $\{\text{vendor, department}\} = \text{Function for Job Attractiveness from Participation} \{\text{Participation Culture by Department}\}$

- Dimensionless

Job Attractiveness from Profit Sharing $\{\text{vendor, department}\} = \text{Sensitivity of Job Attractiveness from Profit Sharing} \{\text{Profit Sharing as Percentage of Salary}\}$

- Dimensionless
- Job attractiveness from the psychological effect of profit sharing as % of salary. The financial effect of profit sharing is captured through the total compensation effect.

Job Attractiveness from Psychological Ownership $\{\text{vendor, department}\} = \text{Job Attractiveness from Profit Sharing} \{\text{vendor, department}\} + \text{Job Attractiveness from Employee Ownership Stake} \{\text{vendor, department}\} + \text{Job Attractiveness from Option Grants} \{\text{vendor, department}\} + \text{Job Attractiveness from Participation} \{\text{vendor, department}\}$

- Dimensionless
- Job attractiveness from psychological effects of employee ownership, participation and profit sharing.
Job Attractiveness Without Reference[vendor, department] = Job Attractiveness for Existing Employees[vendor, department] - Reference Job Attractiveness

- Dimensionless

Layoff Perceived[vendor, department] = Layoff Rate[vendor, department]

- People/Year

Minimum Basis Point of Cumulative Options for Positive Psychological Effect = 1

- 1/Person


- Dimensionless

Job attractiveness is the sum of effects from burnout, layoff and psychological ownership. Additive instead of multiplicative form is used to match the NBER Shared Capitalism dataset.

Past Layoff Forgotten[vendor, department] = Perceived Layoffs[vendor, department] / Time to Forget Past Layoff

- People/Year

Perceived Layoff Fraction[vendor, department] = MIN(ZIDZ(Perceived Layoffs[vendor, department], Total Employees per Department[vendor, department]), 1)

- Dimensionless

Perceived layoff fraction is the perceived layoffs in people's memory divided by total employees, constrained to be less or equal to 1.

Perceived Layoffs[vendor, department] = INTEG (Layoff Perceived[vendor, department] - Past Layoff Forgotten[vendor, department], 0)

- People

Perceived Non Financial Job Attractiveness[vendor, department] = SMOOTH(Non Financial Job Attractiveness[vendor, department], Time to Perceive Job Satisfaction)

- Dimensionless

It takes time for job applicants to perceive non financial job satisfaction occurred inside the company. New hires takes the perceived job satisfaction into consideration.

Profit Sharing as Percentage of Salary[vendor, department] = ZIDZ(Expected Profit Sharing per Employee[vendor, department], Average Salary[vendor]) * 100

- Dimensionless

Profit sharing as percentage of the average salary of employees.

Profit Sharing per Employee[vendor, department] = ZIDZ(Profit Sharing Amount[vendor], Total Employees[vendor])

- $/Person/Year

Profit sharing amount in dollars per employee in each department.

Reference Employee Ownership Stake Relative to Salary = 1

- Year

Used to normalized the table function.

Reference Employees for Reporting Time = 100

- People

Reference Job Attractiveness = 3

- Dimensionless

Reported Average Job Attractiveness[vendor] = SUM(Reported Job Attractiveness[vendor, department] * Total Employees per Department[vendor, department]) / SUM(Total Employees per Department[vendor, department])

- Dimensionless
Average job attractiveness for all employees from all departments.

Reported Job Attractiveness[vendor, department] = SMOOTH(Job Attractiveness for Existing Employees[vendor,department], Reporting Time for Job Attractiveness[vendor])

~ Dimensionless

Reporting Time for Job Attractiveness[vendor] = Function of Reporting Time for Job Attractiveness[Total Employees[vendor]/Reference Employees for Reporting Time]

~ Year

~ The time it takes to survey and report job attractiveness of existing employees is a function of the number of total employees.

Sensitivity of Burnout Effect = 1
~ Dimensionless [0,2,0.1]

Sensitivity of Job Attractiveness from Employee Ownership = 1
~ Dimensionless [0,2,0.1]

Sensitivity of Job Attractiveness from Financial Compensation = 1
~ Dimensionless [0,2,0.1]

Sensitivity of Job Attractiveness from Option Grants = 1
~ Dimensionless [0,2,0.1]

Sensitivity of Job Attractiveness from Participation = 0
~ Dimensionless [0,2,0.1]

Sensitivity of Job Attractiveness from Profit Sharing = 1
~ Dimensionless [0,2,0.1]

Sensitivity of Job Attractiveness on Workweek = 1
~ Dimensionless [0,2,0.1]

Sensitivity of Layoff Effect = 1
~ Dimensionless [0,2,0.1]

Time to Adjust Expected Profit Sharing = 0.5
~ Year

~ It takes half an year to forget about past layoff. This captures the negative effect of layoff (job insecurity) persists a certain time after the time of layoff.

Time to Perceive Job Satisfaction = 0.5
~ Year

~ It takes 6 months to for outside job applicants to perceive job satisfaction from inside the company.

Value of Average Employee Shares Outstanding[vendor, department] = Average Employee Shares Outstanding[vendor,department] * Stock Price[vendor]
~ $/Person

~ Dollar value of the average accumulative employee share outstanding per employee.

Workweek per Year = 50
~ week/Year

Burnout Time[vendor] = 0.25
~ years

~ The time period over which fatigue and burnout develop and dissipate.
Change in Average Workweek[vendor,department] = (Current Workweek[vendor,department] - Recent Average Workweek[vendor,department]) / Burnout Time[vendor]

- Hours/(Year*week)
- The average workweek is an exponential moving average of the work week. Active only after the firm begins operations.

Current Workweek[vendor,department] = Normal Workweek*Effect of Work Pressure on Workweek[Work Pressure[vendor,department]]*Effect of Job Attractiveness on Workweek[vendor,department]
- Hours/week
- The workweek is determined by schedule pressure, which is the ratio of the staff needed in a given department to the staff available in that department. Workweek is a nonlinear function of schedule pressure.

- Hours*Person/Year

Discount Rate for Total Compensation[vendor] = Normal Discount Rate for Compensation + Expected Layoff or Failure Hazard Rate[vendor]
- 1/Year
- The discount rate used to value the NPV of total compensation. Assumes a normal discount rate to capture the time value of money and a risk premium based on the probability of being laid off or of the firm failing.

Effect of Work Pressure on Workweek = (0.0, 4.2), (0.0, 0.6), (0.25, 0.65), (0.5, 0.75), (0.75, 0.87), (1.1, 1.25, 1.15), (1.5, 1.28), (1.75, 1.39), (2.1, 1.48), (2.25, 1.57), (2.5, 1.62), (2.75, 1.66), (3.1, 1.68), (4, 1.7)
- Dimensionless
- The workweek as it depends on schedule pressure. There are minimum and maximum limits on the workweek.

Expected Layoff or Failure Hazard Rate[vendor] = Normal Layoff or Failure Hazard Rate, Relevant Liquidity for Hazard Rate[vendor], 1e+006
- 1/Year
- The hazard rate (per year) that the firm will fail or lay off its employees. Rises as perceived liquidity falls. For simplicity we assume the annual hazard rate of failure is a normal rate divided by perceived liquidity, that is, the hazard rises in inverse proportion to liquidity.

Expected per Share Option Value[vendor,department] = Average Strike Price of Non Vested Options[vendor,department] * Option Value as Fraction of Strike Price[vendor,department]
- $/share
- The per share value of the non vested options of each employee is a function of the difference between the expected share price and the average strike price of their non vested options. The function represents the subjective valuation, in the minds of employees, of the option value (roughly the Black-Scholes value but potentially biased by employee optimism about future share value or volatility.

Expected Present Value of Stock Options[vendor,department] = Expected Value of Non Vested Stock Options[vendor,department] * exp (-Discount Rate for Total Compensation[vendor] * Vesting Period[vendor,department])
- $/Person
- The present value of the average employee's non vested option holdings. Discounted at a specified rate over the vesting period: the higher the discount rate or longer the vesting period, the lower the present value of the options held.
Expected Value of Non Vested Stock Options[vendor,department] = Expected per Share Option Value[vendor,department] * Non Vested Options per Employee[vendor,department]
~ $/Person
~ This variable calculated the value of a typical employee's non vested options if they were converted today. Only the value of non vested options matters to the quit decision since those with vested options can exercise them even after they leave the firm.

Fractional Option Value[vendor,department] = ZIDZ \{ ( Expected Stock Price[vendor] - Average Strike Price of Non Vested Options[vendor,department] ) / Average Strike Price of Non Vested Options[vendor,department] \} 
~ Dimensionless
~ The current average of non vested options relative to the average strike price. Zero if no options are issued.

Function for Expected Option Value([(-1,0),(3,3)],(-1,0),(-0.5,0.05),(0,0.25),(0.5,0.6),(1,1),(2,2),(1000,1000)) 
~ Dimensionless
~ Function for the subjective valuation by employees of their stock options. When stock options are in the money, employees value them close to the current value. As they begin to go underwater, the subjective value gradually declines to zero.

Normal Discount Rate for Compensation = 0.05
~ 1/Year
~ The normal discount rate for total compensation represents the time value of money.

Normal Layoff or Failure Hazard Rate = 0.1
~ 1/Year
~ The normal hazard rate of layoff or business failure, per year.

Normal Workweek = 40
~ Hours/week
~ The standard workweek is assumed to be 40 hours.

Option Value as Fraction of Strike Price[vendor,department] = Function for Expected Option Value( Fractional Option Value[vendor,department] ) 
~ Dimensionless
~ The option value (relative to the average strike price of the non vested options outstanding) is a function of the difference between the current stock price and the strike price. This function represents the employee's subjective valuation of the options, and roughly follows the Black-Scholes concept.

Recent Average Workweek[vendor,department] = INTEG( Change in Average Workweek[vendor,department] , Normal Workweek ) 
~ Hours/week
~ The recent average workweek, used to indicate fatigue and burnout due to sustained high work hours.

Reference Present Value of Total Compensation[vendor,department]=Reference Total Compensation[vendor,department] / ( Normal Discount Rate for Compensation + Normal Layoff or Failure Hazard Rate )
~ $/Person
~ The reference level for the expected present value of total compensation. Represents the employees' aspiration for the present value of their salary and non vested options. Computed as the NPV of the reference total annual compensation employees desire, discounted at a rate that measures the time value of money plus the normal probability of layoff or business failure people assess.

Time to Perceive Work Pressure = 0.083333
~ years
~ The time required to recognize and react to changes in the balance between the work effort required and the work effort available.
Expected Value of Non Vested Stock Grants[vendor, department]=\text{Expected Stock Price[vendor]} \times \exp\{-\text{Discount Rate for Total Compensation[vendor]} \times \text{Stock Grant Vesting Period[vendor,department]}\}$
\sim \$/share

Relevant Liquidity for Hazard Rate[vendor]=\text{MIN}(1, \text{Perceived Liquidity[vendor]})
\sim \text{Dimensionless}
\sim \text{Liquidity relevant for affecting hazard rate is when liquidity is lower than 1. When } >1, \text{ hazard rate stays at the normal rate.}

Salary as Percentage of Industry Average[vendor]=100
\sim \text{Dimensionless } [50,150,1]
\sim \text{Startup's compensation as a fraction of the industry average. 1 means the same as the industry average.}

Value of Company Mission to Employees[vendor,department]=\text{Reference Total Compensation[department]} \times \text{Value of Company Mission to Employees Relative to Reference Compensation[vendor,department]}
\sim \$/\text{Year*Person}
\sim \text{Intrinsic value of working for a company dedicated to environmental sustainability expressed in dollar terms.}

Value of Company Mission to Employees Relative to Reference Compensation[startup,department]=0
Value of Company Mission to Employees Relative to Reference Compensation[incumbent,department]=0
\sim \text{Dimensionless } [0,1]
\sim \text{Value of company mission to employees as a fraction of reference compensation. This is to capture the idea that people may be willing to work for a green company for a lower financial compensation, or for the same compensation, green company may be able to attract a higher quality people. Only effective for green startups and none for incumbent.}

Average Salary[vendor]=\text{ZIDZ}(\text{Salary Expense[vendor]}, \text{Total Employees[vendor]})
\sim \$/\text{Year*People}
\sim \text{Average salary equals the total salary expense divided by total employees.}

Required Experienced Employee Time for Coaching Rookies[vendor,department]=\text{Rookie Employees[vendor,department]} \times \text{Normal Work Hours per Year}
\times \text{Fraction of Experienced Employee Time Needed per Rookie}
\sim \text{Hours*Person/Year}
\sim \text{Each rookie requires a certain amount of coaching, training and mentoring. The total person-hours of effort needed to do so depends on the total number of rookies and the fraction of an FTE experienced persons' time needed to provide the required amount of coaching.}

Work Pressure[vendor,department]=\text{SMOOTHI}(\text{Indicated Work Pressure[vendor,department]}, \text{Time to Perceive Work Pressure}, 1)
\sim \text{Dimensionless}
\sim \text{It takes employees a short time to perceive and react to changes in the balance between the work to be done and the effective work effort available.}

Stock Grant Vesting Period[vendor,department]=3
\sim \text{Year}
\sim \text{The average vesting period for restricted stock grants.}

Reference Total Compensation[department]=100000
\sim \$/\text{Year*Person}
\sim \text{The annual value of total compensation employees expect to earn. }$100,000 \text{ base salary.}

Stock Granted for Existing Employees as Percentage of Industry Compensation[vendor]=0
\sim \text{Dimensionless } [0,200,5]
Stock Granted per Existing Employee[vendor,department] = Value of Stock Granted per Existing Employee[vendor,department] / MAX(1, Stock Price[vendor]) * Switch for Stock Grants
~ shares/(Year*Person)
~ Shares granted per existing employees equals the total value of stock granted per employees ($/year*person) divided by the stock price ($/share), capped at minimum stock price = 1 to prevent extremely large shares granted when stock price is infinitely small.

Total Employees per Department[vendor,department] = Experienced Employees[vendor,department] + Rookie Employees[vendor,department]
~ People
~ Total employees by department.

Desired Options Granted per Employee per Year as Basis Point of Shares Outstanding[vendor] = GAME (0)
~ 1/Person/Year [0,100,1]
~ Options granted per employee per year calculated as the basis point of the total shares outstanding. This measure is used to make the options granted more meaningful (than the absolute number of options) as it compares relative to the total shares.

Expected Stock Price[vendor] = SMOOTH ( Stock Price[vendor], Time for Adjust Expectations for Stock Price )
~ $/share
~ Employees' expectations about the future stock price, which are used here to affect their decision to remain with the firm or quit, adjust slowly to the actual price (the decision to quit is not based on short term changes in share values).

Time for Adjust Expectations for Stock Price = 0.25
~ years
~ The time period over which employees' expectations for the share price change (used to affect their decision to quit or remain with the firm).

Average Strike Price of Non Vested Options[vendor,department] = ZIDZ ( Total Basis of Non Vested Options[vendor,department] , Non Vested Employee Options[vendor,department] )
~ $/share
~ The average basis cost of nonvested options is the total of all strike prices divided by the number of non vested options outstanding. Set to zero if there are no non vested options.

Cumulative Options per Employee as Basis Point of Shares Outstanding[vendor] = ZIDZ ( Cumulative Options per Employee[vendor] , Total Shares Outstanding[vendor] )*Basis Point
~ 1/Person
~ The number of options held by employees as a fraction of the total number of existing shares. Zero prior to entry.

Non Vested Options per Employee[vendor,department] = ZIDZ ( Non Vested Employee Options[vendor,department] , Total Employees per Department[vendor,department] )
~ shares/Person
~ Average non vested options per employee is the ratio of total non vested employees to employees (by department).

Vesting Period[vendor,department] = 3
~ Year
~ The average vesting period for options.

Required VC Financing Effort by Department[vendor,department] = Required VC Financing Effort[vendor]*Proportion of Feasible VC Financing Effort by Department[vendor,department]
~ Person*Hours/Year
~ Desired VC financing effort is assumed to come from sales and engineer proportionally.

---------------------------------------------------------------
*Operating and System Costs
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Energy and Operating Costs[vendor]=Energy Costs[vendor]+Annual Service Fee per Unit[vendor]
  ~ $/Year/Unit

Energy and Operating Costs as Fraction of Incumbent[vendor]=Energy and Operating Costs[vendor]/Energy and Operating Costs[incumbent]
  ~ Dimensionless

Energy and Operating Costs Shortfall as Fraction of Incumbent[vendor]=Energy and Operating Costs as Fraction of Incumbent[vendor]-Targeted Energy and Operating Costs as Fraction of Incumbent[vendor]
  ~ Dimensionless

Incumbent Feature Growth Percentage=0
  ~ Dimensionless [0,100]

Initial Feature Relative to Incumbent=4
  ~ Dimensionless [0,10]

Initial Incumbent Feature Value=Initial Feature Value[incumbent]
  ~ Features

Switch for Product Development[vendor]=IF THEN ELSE(Energy and Operating Costs Shortfall as Fraction of Incumbent[vendor]>0, 1, 0)
  ~ Dimensionless

Targeted Energy and Operating Costs as Fraction of Incumbent[vendor]=0
  ~ Dimensionless

Amortized Capital Cost[vendor]=Switch for Lump Sum Payment * Consumer Price After Subsidy[vendor] * Fractional Annualized Capital Cost + Annual Service Fee per Unit[vendor] + ( 1 - Switch for Lump Sum Payment ) * Annualized Purchase Price[vendor] + Annual Service Fee per Unit[vendor]
  ~ $/Year/Unit
  ~ Switch = 1 if annualized capital cost is calculated as ..... Switch = 0 if annualized capital cost equals annualized price of the product plus the maintenance billing.

  ~ $/Year/Unit

Effect of Functionality on Energy Use[vendor] = Minimum Effect of Functionality on Energy Use
  ~ Dimensionless
  ~ Dimensionless

  ~ $/Year/Unit

Energy Intensity Reduction per Doubling of Features=0.5
  ~ Dimensionless
  ~ The reduction in the energy intensity of the product per doubling of features. The larger this is, the faster energy intensity falls as the features and functionality of the product improve.

  ~ $/Year/Unit

Fractional Annualized Capital Cost = Discount Rate + ( 1 / Product Useful Life )
  ~ 1/Year

Minimum Effect of Functionality on Energy Use=0

277
Dimensionless

Normalized Total Features[vendor] = Feature Value[vendor] / Initial Incumbent Feature Value

Product Useful Life = 20

Sensitivity of Effect of Functionality on Energy Use = \( \frac{\ln(1 - \text{Energy Intensity Reduction per Doubling of Features})}{\ln(2)} \)

Switch for Lump Sum Payment = 1

Feature Value[vendor] = Features[vendor, nonappropriable] \times \text{Nonappropriable Feature Multiple} + Features[vendor, appropriable]

Government Subsidy Percentage = 0

Incumbent Price = 16000 $/Unit

Initial Incumbent Unit Cost = 5000 $/Unit

Initial Markup Ratio = 0.3

Initial Price[vendor] = (1 + Initial Markup Ratio) \times Initial Unit Cost[vendor] $/Unit

Average Competitor Price[vendor] = \sum \text{Price[vendor] \times Order Share[vendor]} $/Unit

Change in Traditional Price[vendor] = (\text{Indicated Price[vendor] - Traditional Price[vendor]}) / \text{Time to Adjust Expected Price} $/Unit/Year

Managers' beliefs about the underlying equilibrium price adjust in response to the gap between the indicated price and the current traditional price level. Expected underlying price adjusts via first-order adaptive expectations to the actual price, constrained to be greater than a minimum level. The Change in Traditional Price for New Entrant is zero unless a firm enters after the start of the simulation. When a firm enters after the start of the simulation the traditional price jumps to the level
of the new entrant, determined by unit costs and other factors. If the firm exits, the traditional price is set to zero through the Change in Traditional Price on Exit.

**Competitor Target Price Premium** = 1

\[ \text{Dimensionless } [0,2,0.05] \]

- Competitors' target price premium relative to firm 1's price.

**Desired Price Premium Relative to Competition**[startup1] = Our Target Price Premium

**Desired Price Premium Relative to Competition**[startup2] = Competitor Target Price Premium

\[ \text{Dimensionless} \]

- The fractional premium (if > 1) or discount (if < 1) the firm desires to achieve relative to the competitor price.

**Effect of Competitor Price on Price**[vendor] = 1 + Sensitivity of Price to Competitor Price \* (Function for Effect of Competitor Price on Price \( ZIDZ \) (Indicated Price Relative to Competition[vendor], Traditional Price[vendor]) - 1)

\[ \text{Dimensionless} \]

- Price rises when indicated price relative to the competition exceeds the firm's expected price. The strength of the effect is controlled by the sensitivity parameter.

**Effect of Costs on Price**[vendor] = 1 + Sensitivity of Price to Costs \* (Function for Effect of Costs on Price \( ZIDZ \) (Unit Cost[vendor], Traditional Price[vendor]) - 1)

\[ \text{Dimensionless} \]

- Price responds to the gap between traders' beliefs about the underlying equilibrium price and their beliefs about the costs of production. When expected costs rise above the expected price, prices tend to rise, and vice versa. Total unit costs include unit fixed and variable costs and the expected level of indirect costs per unit. The function saturates for high and low ratios of costs to the traditional price to ensure robustness.


\[ \$/Unit \]

- When price is set endogenously it is based on the traditional price, modified by various pressures including the level of price relative to unit costs and the competitor price, the demand/supply balance, and the firm's market share relative to its goal for market share.

**Expected Competitor Price**[vendor] = SMOOTHI (Average Competitor Price[vendor], Time to Respond to Competitor Price, Traditional Price[vendor])

\[ \$/Unit \]

- Firm's beliefs about the prices of their competitors. Adjust to the actual average competitor price with a lag representing the time required to update perceptions and beliefs about competitor prices.

**Function for Effect of Competitor Price on Price** \( ([0,0)-(2,2)],[0,0.25],[0,2,0.33],[0,4,0.45],[0,6,0.6],[0,8,0.8],[1,1],[1,2,1.2],[1,4,1.4],[1.6,1.55],[1.8,1.67],[2,1.75]) \)

\[ \text{Dimensionless} \]

- Function determining the impact of competitor prices on price. Linear in the normal operating region, the function saturates for high and low ratios of competitor price to the traditional price to ensure robustness.

**Function for Effect of Costs on Price** \( ([0,0)-(2,2)],[0,0.1],[0,2,0.2],[0,4,0.4],[0,6,0.6],[0,8,0.8],[1,1],[1,2,1.2],[1,4,1.4],[1.6,1.6],[1.8,1.7],[2,1.75]) \)

\[ \text{Dimensionless} \]

- Function determining the impact of unit costs on price. Linear in the normal operating region, the function saturates for high and low ratios of unit costs to the traditional price to ensure robustness.
~ S/Unit
~ Beliefs about the underlying equilibrium price are never less than a minimum price level capturing the variable costs of goods.

~ S/Unit
~ The price indicated by expected competitor prices and the firm's desired premium or discount relative to competitors.

~ Dollars/Unit
~ min price - unit cost = min price * min gross margin, rearrange terms to get min price.

Our Target Price Premium = GAME( 1 )
~ Dimensionless [0,2,0.05]
~ The fractional premium (if > 1) or discount (if < 1) the firm desires to achieve relative to the competitor price.

~ Dimensionless
~ Our price as a fraction of the industry average price. Use to signal how far we are away from the average.

Price for Game=Unit Cost[startup1] * ( 1 + Price Markup for Game / 100)
~ S/Unit
~ When used in gaming mode this is the price of the product as the player sets the price markup.

Price Markup for Game=30
~ Dimensionless
~ Price markup as % of the unit cost, set by the game player.

Sensitivity of Price to Competitor Price = 0.2
~ Dimensionless [0,1,0.05]
~ Strength of the impact of competitor prices on the firm's pricing decision.

Sensitivity of Price to Costs = 0.2
~ Dimensionless
~ Controls the response of price to discrepancies between the expected price and the expected cost of production.

Time to Adjust Expected Price=5
~ Year
~ Trader's belief about the underlying equilibrium price adjust to actual prices over this period.

Time to Respond to Competitor Price = 0.5
~ Year [0,2]
~ The mean time required to update information and beliefs about competitor prices.

~ S/Unit
~ The traditional price is the price managers believe would clear the market if demand and supply were in balance, and no other pressures to change price existed.

Order Share[vendor]=ZIDZ(Firm Attractiveness[vendor], Total Firm Attractiveness)
~ Dimensionless
~ Firm's order share determined by its individual attractiveness comparing with the sum of all firms' attractiveness.
Product Development

Incumbent Features[featuretype]=10, 1
~   Features

Maximum Feasible Feature Factor=10
~   Dimensionless

Maximum Feasible Features[vendor, featuretype]=Incumbent Features[featuretype]*Maximum Feasible Feature Factor
~   Features

Average Feature Lifetime[vendor,featuretype]=10000
~   Year
~   Avg amount of time a feature is useful for

Desired Feature Completion Rate[vendor,featuretype] = MAX ( 0, Feature Shortfall[vendor,featuretype] / Desired Time to Catch Up Features[vendor,featuretype] + Feature Obsolescence Rate[vendor,featuretype] )
~   Features/Year
~   How many features we’d like to develop per month to obtain stock of features we’d like (taking into account features we’re losing from obsolescence) -- allowed to go negative

Desired Time to Catch Up Features[vendor,featuretype] = 0.167, 0.333; 0.167, 0.333; 0.167, 0.333;
~   Year [0,80,0.1]
~   How soon we’d like our features to reach the desired level

Feature Under Development Adjustment Time[vendor,featuretype] = 0.2
~   Year [0,10,0.1]
~   How long to take to adjust FUD to desired level

Initial Features per Type[startup,featuretype]=Incumbent Features[featuretype]*Initial Feature Relative to Incumbent
Initial Features per Type[incumbent,featuretype]=Incumbent Features[featuretype]
~   Features [0,300,0.1]
~   Amount of features product has when firm starts compared to competitors. 110, 4; 110, 4; 110, 4

Nonappropriable Feature Multiple=10
~   Dimensionless
~   Avg multiple of value of appropriable features that nonappropriable features have

Initial Features[vendor] = SUM ( Initial Features per Type[vendor,featuretype] )
~   Features

Feature Value Relative to Incumbent[vendor] = Feature Value[vendor] / Feature Value[incumbent]
~   Dmnl
~   Features of our company compared to incumbent (0 is no features, 1 is equiv features to incumbent)

~   Features/Year
~   How many features per month we need to add (or subtract) from FUD

Desired Feature Under Development[vendor,featuretype] = Desired Feature Completion Rate[vendor,featuretype] * Average Feature Development Time[vendor]
~   Features
~   How many features we need under development to maintain the rate of feature development we desire
Desired Features\[startup,featuretype\]= Maximum Feasible Features\[startup,featuretype\]
Desired Features\[incumbent,featuretype\]=MIN(Maximum Feasible Features\[incumbent,featuretype\],
Features\[incumbent,featuretype\]*(1+Incumbent Feature Growth Percentage/100))

~ Features
~ How many features we desire (based on how many features competitors have, and how we want to compare to competitors)

Feature Completion Rate\[vendor,featuretype\] = Feature Completion Rate 3\[vendor,featuretype\]
~ Features/Year
~ The rate at which features are developed into the product determined by how many features were started and providing a 3rd order delay to complete them in the avg feature devl time

Feature Obsolescence Rate\[vendor,featuretype\] = Features\[vendor,featuretype\] / Average Feature Lifetime\[vendor,featuretype\]
~ Features/Year
~ Features that go out of date per month

Feature Shortfall\[vendor,featuretype\] = (Desired Features\[vendor,featuretype\] - Features\[vendor,featuretype\])\*Switch for Product Development\[vendor\]
~ Features
~ How many features we’re missing compared to what we desire.

Features\[vendor,featuretype\] = INTEG( Feature Completion Rate\[vendor,featuretype\] - Feature Obsolescence Rate\[vendor,featuretype\], , Initial Features per Type\[vendor,featuretype\] )
~ Features
~ Features of the product

Product Features Under Development\[vendor,featuretype\] = INTEG( Feature Start Rate\[vendor,featuretype\] - Feature Completion Rate\[vendor,featuretype\], 0)
~ Features
~ Features that are being worked on by the engineering staff

***************************************************************
Prospects and Adopters
***************************************************************

Initial Potential Customers=1
~ Prospects

Normal Adopter Generation Time Scale=0.1
~ Dimensionless

Normal Hot Prospect Generation Time Scale= 0.3
~ Dimensionless

Normal Prospect Generation Time Scale=0.1
~ Dimensionless

Potential Prospect Generation Time Scale=0.5
~ Dimensionless

Total Prospect Sales=Total Prospects*Unit Purchased per Adopter
~ Unit
~ Sum up all prospect sales contacted by each firm, since they call be prospect sales for a firm, i.e. a firm a "steal" a prospect contacted by other firms.

Initial Adopters = 0
~ Prospects
~ The initial number of Adopters (active users of the product).
Initial Hot Prospects = 0
- Prospects

Initial Potential Prospects = 0
- Prospects [0,100,10]

Initial Prospects = 0
- Prospects
- Start with no prospects

- Prospects
- Total non purchasers and adopters.

Addressable Fraction of Population = SUM (Firm Attractiveness[vendor]) / Total Attractiveness Including Alternative
- Dimensionless
- Addressable Fraction of Population is the sum of all startups over the total including the incumbent.

Attractiveness of Current Practice = 1
- Dimensionless

Effect of Sales Effort on Adopter Generation Rate[Firm,vendor] = Function for Prospect Generation Rate (ZIDZ (Potential Adopter Generation Rate From Sales Effort[Firm,vendor], Normal Adopter Generation Rate[Firm]))
- Dimensionless

Effect of Sales Effort on Hot Prospect Generation Rate on Potential Hot Prospect Generation[Firm] = Function for Prospect Generation Rate (ZIDZ (Potential Hot Prospect Generation Rate From Sales Effort[Firm], Normal Hot Prospect Generation Rate[Firm]))
- Dimensionless

Effect of Sales Effort on Poaches[customer] = Function for Prospect Generation Rate (ZIDZ (Potential Poaches From Sales Effort[customer], Normal Poaching Rate[customer]))
- Dimensionless

Effect of Sales Effort on Potential Prospect Generation = Function for Prospect Generation Rate (ZIDZ (Potential Potential Prospect Generation Rate From Sales Effort, Normal Potential Prospect Generation Rate))
- Dimensionless

Effect of Sales Effort on Prospect Generation Rate on Potential Prospect Generation[Firm] = Function for Prospect Generation Rate (ZIDZ (Potential Prospect Generation Rate From Sales Effort[Firm], Normal Prospect Generation Rate[Firm]))
- Dimensionless

Firm Specific Adopter Generation Rate[customer,vendor] = IF THEN ELSE (customer <> vendor, Potential Adopter Generation Rate[customer,vendor] * Order Share[vendor], 0)
Firm Specific Adopter Generation Rate[Firm,none] = 0
Firm Specific Adopter Generation Rate[none,vendor] = Potential Adopter Generation Rate[none,vendor] * Order Share[vendor]
- Prospects/Year
- Firm specific adopter generation rate [customer, vendor] is the adopter generate rate switching from prospects currently adopting [customer] to [vendor]'s product. It is determined by the potential adopter generation rate (induced by vendor firm's sales effort) times the [vendor]'s order share. It is assumed that after prospects of [customer] being contacted by [vendor], prospect [customer] compares all firms' attractiveness and switch to [vendor] according to [vendor]'s relative attractiveness. The rest drops out into lost prospects and no switching to other competitor since direct sales effort is assumed to be needed to switch.
Function for Prospect Generation Rate \( (0,0)-(2,2), (0,0), (0.25,0.33), (0.5,0.62), (0.75,0.85), (1,1), (1.25,1.1), (1.5,1.17), (1.75,1.22), (2,1.25) \)

- Dimensionless
- Fuzzy min function with maximum set at 1.25 times of normal prospect generation rate.

Hot Prospect Generation Rate[customer] = Potential Hot Prospect Generation Rate[customer] \* Prospect Generation Fraction[customer]

Hot Prospect Generation Rate[none] = Potential Hot Prospect Generation Rate[none]

Hot prospect loss rate[Firm] = SUM (Potential Adopter Generation Rate[Firm,vendor] - Firm Specific Adopter Generation Rate[Firm,vendor])

- Prospects/Year
- Those hot prospects exposed to sales effort who do not become purchasers become lost prospects.

Initial Population=100000

Lost Prospect Regain Time = 1

- Year
- Amount of time before a lost prospect will reconsider becoming a prospect


- Prospects
- Former prospects who currently are not considering adopting the product

Normal Adopter Generation Time=Normal Adopter Generation Time Scale*Sales Cycle Time

- Year [0,2]
- Minimum amount of time it takes to persuade a prospect to trial the product

Normal Hot Prospect Generation Time=Normal Hot Prospect Generation Time Scale*Sales Cycle Time

- Year [0,1]
- Average amount of time it takes to persuade a prospect to seriously consider purchasing

Normal Poach Time=10

- Year [0,7]
- Average amount of time it takes for an adopter to be poached by other firms.

Normal Potential Prospect Generation Time=Potential Prospect Generation Time Scale*Sales Cycle Time

- Year [0,7]
- Average amount of time it takes for a potential prospect to become aware of product and become a prospect

Normal Prospect Generation Time=Normal Prospect Generation Time Scale*Sales Cycle Time

- Year [0,1]
- Average amount of time it takes for a potential prospect to become aware of product and become a prospect

Percentage Growth Rate in Total Population=0

- 1/Year [0,20,1]
- Percentage growth rate per year in the total population of firms in the target industry.


Poaches[none] = 0

- Prospects/Year

Population Growth=(Percentage Growth Rate in Total Population/100) \* Total Population
Prospects/Year

Potential Adopter Generation Rate[Firm,vendor] = Normal Adopter Generation Rate[Firm] \times Effect of Sales Effort on Adoptor Generation Rate[Firm,vendor]

\sim \text{Prospects/Year}
\sim \text{The rate at which prospects convert to purchasers (or dropout and remain with their current provider) is modeled using the fuzzy min function which caps at 1.25 times of normal purchaser generation rate.}

Potential Customers = \text{MAX ( Initial Potential Customers, Indicated Adopters - Total Adopters and Prospects )}

\sim \text{Prospects}
\sim \text{Potential customer is determined by the addressable market less total adopters and prospects. This is an auxiliary variable since it is fully determined by indicated adopters and total adopters and prospects.}

Potential Hot Prospect Generation Rate[Firm] = Normal Hot Prospect Generation Rate[Firm] \times Effect of Sales Effort on Hot Prospect Generation Rate on Potential Hot Prospect Generation[Firm]

\sim \text{Prospects/Year}
\sim \text{The rate at which prospects convert to hot prospects (or dropout and remain with their current provider) is modeled using the fuzzy min function which caps at 1.25 times of normal hot prospect generation rate.}

Potential Poaches[customer] = Normal Poaching Rate[customer] \times Effect of Sales Effort on Poaches[customer]

\sim \text{Prospects/Year}
\sim \text{The rate at which potential prospects convert to prospects (or dropout and remain with their current provider) is modeled using the fuzzy min function which caps at 1.25 times of normal prospect generation rate.}

Potential Poaches From Sales Effort[customer] = \text{SUM ( Sales Productivity[vendor] \times Sales Effort for Targeted Adopters[customer,vendor] )}

\sim \text{Prospects/Year}
\sim \text{Potential prospect generation from sales effort equals sales effort times its productivity.}

Potential Potential Prospect Generation Rate From Sales Effort = \text{SUM ( Sales Productivity[vendor] \times Effective Sales Effort for Potential Customers[vendor] )}

\sim \text{Prospects/Year}
\sim \text{Potential prospect generation from sales effort equals sales effort times its productivity.}

Potential Prospect Generation[none] = Normal Potential Prospect Generation Rate \times Effect of Sales Effort on Potential Prospect Generation

Potential Prospect Generation[customer] = 0

\sim \text{Prospects/Year}

Potential Prospect Generation Rate[Firm] = Normal Prospect Generation Rate[Firm] \times Effect of Sales Effort on Prospect Generation Rate on Potential Prospect Generation[Firm]

\sim \text{Prospects/Year}
\sim \text{The rate at which potential prospects convert to prospects (or dropout and remain with their current provider) is modeled using the fuzzy min function which caps at 1.25 times of normal prospect generation rate.}

Potential Prospect Generation Rate From Sales Effort[Firm] = \text{SUM ( Sales Productivity[vendor] \times Sales Effort for Targeted Potential Prospects[Firm,vendor] )}

\sim \text{Prospects/Year}
\sim \text{Potential prospect generation from sales effort equals sales effort times its productivity, summing from all vendors.}

Potential Prospect Loss Rate[Firm] = Potential Prospect Generation Rate[Firm] - Prospect Generation Rate[Firm]

\sim \text{Prospects/Year}
\sim \text{Those potential prospects exposed to sales effort who do not become prospects become lost prospects.}
Prospect Generation Fraction[vendor] = 1 - Order Share[vendor]
   ~ Dimensionless
   ~ The fraction of potential prospects converting to prospects is the sum of
     the fractions choosing one of the startups, which is the complement of the
     fraction choosing to stay with the incumbent.

Prospect Generation Rate[customer] = Potential Prospect Generation Rate[customer] * Prospect Generation
   Fraction[customer]
Prospect Generation Rate[none] = Potential Prospect Generation Rate[none]
   ~ Prospects/Year

Prospect Loss Rate[Firm] = Potential Hot Prospect Generation Rate[Firm] - Hot Prospect Generation Rate[Firm]
   ~ Prospects/Year
   ~ Those prospects exposed to sales effort who do not become hot prospects become lost prospects.

Prospect Regain Rate[Firm] = Lost Prospects[Firm] / Lost Prospect Regain Time
   ~ Prospects/Year
   ~ Rate at which lost prospects become potential prospects again.

Sales Effort for Targeted Adopters[customer,vendor] = Effective Sales Effort for Poaching[vendor] * Share of Targeted
   Adopters[customer]
   ~ Person*Hours/Year
   ~ Sales effort by [vendor] that targets potential prospects [Firm].

Sales Effort for Targeted Hot Prospects[Firm,vendor] = Effective Sales Effort for Hot Prospects[vendor] * Share of
   Targeted Hot Prospects[Firm]
   ~ Person*Hours/Year
   ~ Sales effort by [vendor] that targets hot prospects [Firm].

Sales Effort for Targeted Potential Prospects[Firm,vendor] = Effective Sales Effort for Potential Prospects[vendor] * 
   Share of Targeted Potential Prospects[Firm]
   ~ Person*Hours/Year
   ~ Sales effort by [vendor] that targets potential prospects [Firm].

Sales Effort for Targeted Prospects[Firm,vendor] = Effective Sales Effort for Prospects[vendor] * Share of Targeted
   Prospect[Firm]
   ~ Person*Hours/Year
   ~ Sales effort by [vendor] that targets hot prospects [Firm].

Share of Targeted Adopters[customer] = ZIDZ ( Adopters[customer] , Total Adopters )
   ~ Dimensionless

   ~ Dmnl

   ~ Dimensionless

Share of Targeted Prospect[Firm] = ZIDZ ( Prospects[Firm] , Total Prospects )
   ~ Dmnl
   ~ The share of prospects currently using [Firm] firm’s product out of total prospects.

Total Adopters = SUM ( Adopters[customer] )
   ~ Prospects
   ~ Sum of all potential prospects, including the existing and new.

Total Adopters and Prospects = SUM ( Total Prospects and Adopters by Firm[Firm] )
   ~ Prospects
   ~ The total existing population of prospects who have adopted any one of the
     products from incumbent or startups is the sum of all those in the
     existing prospect chain, including adopters.

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Total Attractiveness Including Alternative = SUM ( Firm Attractiveness[vendor!] ) + Attractiveness of Current Practice
~ Dimensionless

Total Hot Prospects = SUM ( Hot Prospects[Firm!] )
~ Prospects
~ Sum of all hot prospects.

Total Lost Prospects = SUM ( Lost Prospects[Firm!] )
~ Prospects
~ The sum of all lost prospects by their current provider status.

Total Potential Prospects = SUM ( Potential Prospects[Firm!] )
~ Prospects
~ Sum of all potential prospects, including the existing and new.

Total Prospects = SUM ( Prospects[Firm!] )
~ Prospects
~ Sum of all hot prospects.

Total Population = INTEG( Population Growth , Initial Population )
~ Prospects
~ Total population grows at an exogenous rate.

*****************************************************

Salary
*****************************************************

Average Salary by Department[vendor,department]=xIDZ(Salary Expense per Department[vendor,department],Total Employees per Department[vendor,department],Reference Total Compensation[department])
~ $/Year/People
~ Average yearly cost per employee is determined by the total salary divided by total employee in each department.

Rookie Salary[vendor, department]=Experienced Salary[vendor,department]*Rookie Compensation Relative to Experienced
~ $/(Year*People)

Employee Proportion by Department[vendor,department] = ZIDZ ( Total Employees per Department[vendor,department] , Total Employees[vendor] )
~ Dimensionless
~ Proportion of workforce made up of people from each department.

Rookie Compensation Relative to Experienced=0.667
~ Dimensionless
~ The fraction of the compensation of an experienced employee paid to a new hire.

~ Dollars/Year
~ Total Loaded Salary for entire company by department.

Sales Force Fraction[vendor,sales] = ZIDZ ( Total Employees per Department[vendor,sales] , Total Employees[vendor] )
~ Dimensionless
~ Total sales employees as a fraction of total work force.

Value of Options Granted for Existing Employees[vendor] = SUM ( Value of Options Granted per Existing Employee[vendor,department!] ) * Total Employees per Department[vendor,department!] )
~ $/Year

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Effective Sales Effort[vendor] = Rookie Effective Work Effort[vendor, sales] + Experienced Work Effort for Non Administrative Work[vendor, sales]
   ~ Person*Hours/Year
   ~ Effort devoted to sales after allocated to grant and VC applications.

Effective Sales Effort for Hot Prospects[vendor] = Fractional Sales Effort for Hot Prospects[vendor] * Effective Sales Effort[vendor]
   ~ Persons*Hours/Year
   ~ Total number of hours spent by the sales force on decisions per month

Effective Sales Effort for Poaching[vendor] = Fractional Sales Effort for Poaching[vendor] * Effective Sales Effort[vendor]
   ~ Person*Hours/Year

Effective Sales Effort for Potential Customers[vendor] = Fractional Sales Effort for Potential Customers[vendor] * Effective Sales Effort[vendor]
   ~ Person*Hours/Year
   ~ Sales effort by [vendor] that targets potential prospects [Firm].

Effective Sales Effort for Potential Prospects[vendor] = Fractional Sales Effort for Potential Prospects[vendor] * Effective Sales Effort[vendor]
   ~ Persons*Hours/Year
   ~ Total number of hours spent by the sales force on persuasion per month

Effective Sales Effort for Prospects[vendor] = Fractional Sales Effort for Prospects[vendor] * Effective Sales Effort[vendor]
   ~ Persons*Hours/Year
   ~ Total number of hours spent by the sales force on persuasion per month

   ~ Prospects
   ~ Prospects who have been qualified to be more likely to purchase and/or are trialing the product

Potential Adopter Generation Rate From Sales Effort[Firm, vendor] = Sales Effort for Targeted Hot Prospects[Firm, vendor!] * Sales Productivity[vendor]
   ~ Prospects/Year
   ~ Potential purchaser generation from sales effort equals sales effort times its productivity.

Potential Hot Prospect Generation Rate From Sales Effort[Firm] = SUM ( Sales Effort for Targeted Prospects[Firm, vendor!] * Sales Productivity[vendor!] )
   ~ Prospects/Year
   ~ Potential hot prospect generation from sales effort equals sales effort times its productivity.

   ~ Prospects
   ~ Potential prospects [X] are adopters who use X's product but are potential prospects targeted by other competitor firms.

   ~ Prospects
   ~ Potential customers that have been selected to apply sales effort to persuade to trial the product.

Fractional Sales Effort for Hot Prospects[vendor] = ZIDZ ( Total Normal Purchase Rate * Hot Prospect Emphasis Multiplier[vendor!], Weighted total prospects[vendor!] )
   ~ Dimensionless [0, 1]
Percent of effort of sales people applied to persuading prospects to seriously consider purchasing

Fractional Sales Effort for Poaching[vendor] = ZIDZ ( Total Normal Poaching Rate * Poaching Emphasis Multiplier[vendor] , Weighted total prospects[vendor] )

- Dimensionless
- Fraction of sales effort to make sure purchasers start using product

Fractional Sales Effort for Potential Customers[vendor] = ZIDZ ( Normal Potential Prospect Generation Rate * Potential Customers Emphasis Multiplier[vendor] , Weighted total prospects[vendor] )

- Dimensionless


- Dimensionless
- Percent of sales effort devoted to converting potential prospects to prospects

Fractional Sales Effort for Prospects[vendor] = ZIDZ ( Total Normal Hot Prospect Generation Rate * Prospect Emphasis Multiplier[vendor] , Weighted total prospects[vendor] )

- Dimensionless [0,1]
- Percent of effort of sales people applied to persuading prospects to trial

Sales Productivity Change from Shock= Step(Shock Size, Competition Shock Startup Time)

- Prospects/(Person*Hour)

Shock Size=0

- Prospects/(Person*Hour) [0,0.1,0.01]

Sales Productivity[vendor]=Normal Sales Productivity*Firm Attractiveness[vendor]

- Prospects/(Person*Hour)
- Sales productivity is boosted by firm attractiveness. The more attractive the product is, the more productive sales rep is.

Normal Sales Productivity=[Reference Sales Effort Productivity-Sales Productivity Change from Shock]/(Sales Cycle Time/Reference Sales Cycle Time)

- Prospects/(Person*Hour)
- Reference sales productivity is determined by the reference sales cycle time of 1 year, i.e. sales productivity given 1 year sales cycle. When one shorten sales cycle time, normal sales productivity increases proportionally, i.e. sales effort is more productive with a shorter sales cycle.

Effect of Firm Attractiveness on Sales Productivity[vendor]=1 + ( Maximum Effect of Firm Attractiveness on Sales Productivity - 1) * Sensitivity of Firm Attractiveness on Sales Productivity*Firm Attractiveness[vendor]

- Dimensionless
- The higher the attractiveness, the higher the sales productivity, capped at the max effect.

Maximum Effect of Firm Attractiveness on Sales Productivity=1.2

- Dimensionless
- The maximum increase in sales productivity from feature, relative to the value of sales productivity in the situation where there is no feature.

Reference Sales Cycle Time=1

- Year

Sensitivity of Firm Attractiveness on Sales Productivity=1
Sales Cycle Time = 1
~ Year [0.2, 2, 0.1]
~ Sales Cycle Time determines the normal time it takes to move sales. However, the actual sale rate is determined by sales productivity. A short sales cycle can be represented by a high sales productivity + short sales cycle time together, so one is how long it take to move sales by sales people, the other is the normal rate.

Firm Attractiveness[incumbent] = Incumbent Firm Attractiveness
~ Dimensionless

Firm Attractiveness depends on various factors such as total operating and system costs (which is driven by better product development and lower amortized capital cost from lower price), customer support, WOM and marketing. Attractiveness is zero if Company in Operation Switch is turned off.

Reference Sales Effort Productivity = 0.043
~ Prospects/(Person*Hour) [0, 0.1, 0.001]
~ Sales effort productivity attained at the reference sales experience level.

Reference Sales Effort Productivity = 0.043
~ Prospects/(Person*Hour) [0, 0.1, 0.001]
~ Sales effort productivity attained at the reference sales experience level.

Shares Outstanding
Shares Outstanding

Total Former Employee Shares[vendor] = SUM(Former Employee Shares[vendor, department!])
~ shares

~ $

Percentage of Former Employee Ownership[vendor] = Total Former Employee Shares[vendor] / Total Shares Outstanding[vendor] * 100
~ Dimensionless

~ $/Year
~ Net income after subtracting profit sharing.

Gross Profit[vendor] = Revenue[vendor] - Billing for COGS[vendor]
~ $/Year
~ Gross profit is the difference between revenue and COGS.

TIME STEP = 0.0625
~ Year [0, ?]
~ The time step for the simulation.

Financing Required[vendor] = MAX (0, Adjustment to Financing for Cash[vendor] - Cash Flow Before Financing[vendor])
~ $/Year
~ The financing the firm requires is (nonnegative part of) the amount needed to adjust the cash balance to the target level less firm's cash flow before financing. Note that we do not model the possibility of share buybacks (financing required is constrained to be nonnegative).
Expected Long Run Return on Sales = SMOOTH3( Indicated Industry Return on Sales, Time to Adjust
Expected Long Run Return on Sales, Initial Expected Return on Sales)
~ Dimensionless
~ Investors’ expectation for operating profit as a fraction of sales revenue
  in the long run. Adjusts gradually from the initial level to the indicated level.

Expected Present Value of Profit = MAX(0, Expected Net Income) / Growth Adjusted Discount
Factor
~ $\$
~ The expected present value of the firm’s profit is the net present value
  of expected net income, adjusted for future expected growth. The growth
  adjusted discount factor is based on the discount rate for earnings,
  adjusted to reflect investors’ expectations for future growth in earnings.
  Constrained to be nonnegative (in the case where expected net income is
  negative, such as when the firm consistently loses money).

Growth Adjusted Discount Factor = IF THEN ELSE ( Discount Rate - Expected Growth in Revenue >
0.04, Discount Rate - Expected Growth in Revenue, 0.04 * exp( Sensitivity of Valuation to Rapid Growth *
( Discount Rate - Expected Growth in Revenue - 0.04 ) )
~ 1/Year
~ The discount rate used to value the expected earnings of the firm is a
  nonlinear function of the discount rate and the expected rate of growth in
  future earnings. Based on the formula for the NPV of an exponentially
  growing earnings stream, E(0)/(d-g), where E(0) is current earnings, d
  is the discount rate, and g is expected growth. The nonlinear function
  keep the effective discount rate nonnegative when denominator < 0. The
  minimum value of the function is the inverse of the maximum P/E ratio the
  capital markets are willing to pay.

IPO Date[incumbent]=1000
IPO Date[startup]= GAME (1000)
~ Year [0,21,1]
~ The date at which the company goes public by selling a substantial amount of its equity for cash.

Recent Sales Revenue = SMOOTH( Revenue, Financial Results Reporting Time , 0)
~ $/Year
~ Perceived Sales revenue. Actual sales revenue delayed
  by the time it takes to report financial results.

Shares Outstanding = INTEG( IPO Shares+New Shares Issued to Public+Shares Issued to
VCs+Shares to Employees from Option Exercise+Shares to Employees from Stock Grants, Founder
Shares Outstanding)
~ shares
~ The number of shares outstanding increases when new shares are issued for
  fundraising purposes, or when employees exercise options.

Market Capitalization = MAX( Breakup Value, Expected Present Value of Profit * Pre IPO
Discount, Company in Operation Switch
~ $
~ The market value of the firm is the greater of the expected present value
  of future profits or the breakup value of the firm. Expected profits are
  discounted prior to the IPO.

Public Shares Outstanding = INTEG( Increase in Public Shares , 0)
~ shares

Total Employee Shares Outstanding from Stock Grants = SUM(Employee Shares)
~ shares

Increase in Public Shares = IPO Shares + New Shares Issued to Public
Average Employee Net Worth\[\text{vendor}\] = \text{ZIDZ}(\text{Employee Net Worth}[\text{vendor}], \text{Total Employees}[\text{vendor}])

\sim \$/\text{Person}

\text{EO Error}[\text{vendor}] = \text{Percentage of Employee Ownership}[\text{vendor}] - \text{Percentage of Employee Stock Grants}[\text{vendor}] - \text{Percentage of Exercised Options}[\text{vendor}] - \text{Percentage of Employee Options}[\text{vendor}]

\sim \text{Dimensionless}

\text{Founders Shares Outstanding for Game Display}[\text{vendor}] = \text{Founders Shares Outstanding}[\text{vendor}]

\sim \text{shares}

\text{IPO Likelihood}[\text{vendor}] = \text{IF THEN ELSE}(\text{Expected Present Value of Profit}[\text{vendor}] > \text{Funds to be Raised in IPO}[\text{vendor}], 1, 0)

\sim \text{Dimensionless}

\sim \text{When expected present value of profit is greater than the funds to be raised in IPO, investors are willing to invest, IPO is likely to be accepted by the market.}

\text{Shares Outstanding Plus Options}[\text{vendor}] = \text{Shares Outstanding}[\text{vendor}] + \text{Cumulative Employee Options}[\text{vendor}]

\sim \text{shares}

\text{Shares Outstanding Error}[\text{vendor}] = (\text{Total Shares Outstanding}[\text{vendor}] - \text{Shares Outstanding Plus Options}[\text{vendor}]) / \text{Shares Outstanding Plus Options}[\text{vendor}]

\sim \text{Dimensionless}

\text{Shares to Employees from Stock Grants}[\text{vendor}] = \text{SUM}(\text{Stock Grants Vested}[\text{vendor,department}])

\sim \text{shares/Year}

\text{Stock Valuation Factor for VC Financing} = 3

\sim \text{Dimensionless}

\sim \text{This is the factor used to determine stock valuation for VC financing. The internal stock price at the beginning is determined by the initial capital the founders have, which does not reflect the full value of the firm. By multiplying this factor, it reflects other valuation factor such as the value of the technology the firm has.}

\text{Stock Valuation for VC Financing}[\text{vendor}] = \text{Stock Price}[\text{vendor}] \times \text{Stock Valuation Factor for VC Financing}

\sim \$/\text{share}

\text{Earnings per Share}[\text{vendor}] = \text{Net Income Net of Profit Sharing}[\text{vendor}] / \text{Shares Outstanding}[\text{vendor}]

\sim \$/\text{(Year*shares)}

\sim \text{Earnings per share is net income divided by the number of shares outstanding.}

\text{Employee Shares Outstanding from Exercised Options}[\text{vendor,department}] = \text{INTEG}(\text{Increase in Employee Shares from Exercised Options}[\text{vendor,department}], 0)

\sim \text{shares}

\text{Founders Shares Outstanding}[\text{vendor}] = 1e+006

\sim \text{shares}

\sim \text{The number of shares outstanding when the company starts business.}

\text{Fraction of Financing from Equity}[\text{vendor}] = \text{Function for Fraction of Financing from Equity}(\text{ZIDZ}(\text{Expected Present Value of Profit}[\text{vendor}], \text{Required Present Value of Profits}[\text{vendor}]))

\sim \text{Dimensionless}

\sim \text{The fraction of financing required raised through stock sales to the public declines as the market's expectations of the NPV of future profits falls relative to the value investors require.}

\text{Function for Fraction of Financing from Equity} ([(0,0)-\{1,1\}],\{(0,0),(0.2,0),(0.4,0.05),(0.6,0.15),(0.8,0.9),(1,1),(100,1)})

\sim \text{Dimensionless}
The firm's willingness to sell additional shares to the public falls as the stock price drops relative to the indicated level.

Funds Raised From VCs[vendor]=Switch for VC Application Period[vendor] * Switch for Adequate VC Financing Effort[vendor] * VC Decision Switch[vendor] * PULSE (Time, 0) * MIN (Available VC Financing[vendor], VC Financing Asking Amount[vendor]) / TIME STEP + Follow On Investments[vendor]

~ $/Year
~ Funds raised from VCs at the VC decision date is the lesser of what VCs are willing to invest and what the firm is asking.

Funds to be Raised from Equity Sales[vendor]=Fraction of Financing from Equity[vendor] * Financing Required[vendor] $/Year
~ The firm seeks to raise a fraction of its financing needs through sale of shares to the public.

~ $/(Year*share)
~ The ratio of total gross margin to the number of shares outstanding.

Increase in Employee Shares from Exercised Options[vendor, department]=Options Exercised[vendor, department] shares/Year

Increase in VC Shares[vendor] = Shares Issued to VCs[vendor] shares/Year

Indicated Shares to be Issued at IPO[vendor]=ZIDZ (Funds to be Raised in IPO[vendor], Stock Price[vendor])
~ shares
~ The number of shares sold to the public in the IPO. Determined by the funds raised and the share price.

IPO Shares[vendor]=IPO Likelihood[vendor] * PULSE (IPO Date[vendor], TIME STEP) * Indicated Shares to be Issued at IPO[vendor] / TIME STEP shares/Year
~ The shares issued at the IPO date. The entire value of the IPO is issues in one time step.

Minimum Return on Sales for Valuation = 0.02
~ Dimensionless [0.0, 0.1, 0.01]
~ The minimum return on sales investors would require to be willing to buy secondary issues.

Minimum Returns Required at IPO = 1e+007 $/Year
~ The minimum capital the firm needs to raise in their IPO.

New Shares Issued to Public[vendor] = ZIDZ (Funds to be Raised from Equity Sales[vendor], Stock Price[vendor]) * Switch to Allow Secondary Sales[vendor] shares/Year
~ The firm issues shares to the public to finance its cash flow requirements and maintain normal liquidity. Prior to the IPO, these shares represent the equity sold to venture capitalists in private placements. After the IPO they represent secondary public offerings.

Percentage of Employee Ownership[vendor]=Employee Shares Outstanding and Options[vendor] / Total Shares Outstanding[vendor] * 100 Dimensionless
~ Employee ownership calculated from both employee shares from exercised options and direct shares granted.

Percentage of Exercised Options[vendor]=Total Employee Shares Outstanding from Exercised Options[vendor] / Total Shares Outstanding[vendor] * 100 Dimensionless
Employee ownership calculated from both employee shares from exercised options and direct shares granted.

Percentage of Founders Ownership = Founders Shares Outstanding / Total Shares Outstanding * 100
~ Dimensionless

Percentage of Public Ownership = Public Shares Outstanding / Total Shares Outstanding * 100
~ Dimensionless

Percentage of VC Ownership = VC Shares Outstanding / Total Shares Outstanding * 100
~ Dimensionless

Price Earnings Ratio = MAX ( 0, ZIDZ ( Stock Price, Earnings per Share ) )
~ Year
~ The Price Earnings Ratio is the ratio of the stock price to earnings per share. It is set to zero if earnings are zero or less.

Price over Gross margin Ratio = MAX ( 0, ZIDZ ( Stock Price, Gross Margin per Share ) )
~ Year
~ The ratio of the stock price to gross margin per share. Set to zero if gross margin is negative.

Required Present Value of Profits = Recent Sales Revenue * Return on Sales for Valuation / Growth Adjusted Discount Factor
~ $
~ The market valuation the firm would have given recent sales and the expected return on sales, and discounted by the growth adjusted rate. Does not include the breakup value of the firm's assets.

Return on Sales for Valuation = MAX ( Minimum Return on Sales for Valuation , Expected Long Run Return on Sales )
~ Dimensionless
~ The return on sales investors expect to be willing to buy shares.

Shares Issued to VCs = ZIDZ ( Funds Raised From VCs , Stock Valuation for VC Financing )
~ shares/Year

Shares to Employees from Option Exercise = SUM ( Options Exercised )
~ shares/Year
~ The number of shares outstanding increases with the sum of the options exercised by all types of employees.

Switch to Allow Secondary Sales = IF THEN ELSE ( Time > IPO Date , 1, 0 )
~ Dimensionless
~ Secondary sales cannot occur until after the firm has gone public.

VC Financing Asking Amount = GAME ( MAX(0, Financing Required*Desired Years of Runway) )
~ $
~ The amount a firm asks for from VC financing is the desired cash for the desired years of runway which equals to financing required times desired years of runway.

VC Shares Outstanding = INTEG( Increase in VC Shares, 0)
~ shares

Additional Funds to be Raised in IPO = 0
~ $

Employee Net Worth = Market Capitalization * Percentage of Employee Ownership / 100

Founders Net Worth[vendor]=Market Capitalization[vendor]*Percentage of Founders Ownership[vendor]/100 $ Founder's net worth is the total market cap times its percentage of ownership.

Funds to be Raised in IPO[vendor]=MAX(Minimum Returns Required at IPO, VC Financing Asking Amount[vendor]+Additional Funds to be Raised in IPO) $

Percentage of Employee Stock Grants[vendor]=Total Employee Shares Outstanding from Stock Grants[vendor]/ Total Shares Outstanding[vendor] * 100 % Employee ownership calculated from both employee shares from exercised options and direct shares granted.


Former Employee Shares[vendor,department]= INTEG (Employee Shares Exiting[vendor,department]-Repurchased Employee Shares[vendor, department], 0) shares Shares owned by ex-employees who leave the company.

Stock Price[vendor]= ACTIVE INITIAL [Market Capitalization[vendor] / Shares Outstanding[vendor],1] $/share The stock price per share is the firm's total market value divided by the number of shares outstanding.

Employee Shares[vendor,department]= INTEG (Stock Grants Vested[vendor,department]-Employee Shares Exiting[vendor,department]+Repurchased Employee Shares[vendor, department], 0) shares The number of vested stock grants increases as non vested stock grants vest.

Stock Grants Vested[vendor,department]=Non Vested Stock Grants[vendor,department]/Stock Grant Vesting Period[vendor,department] shares/Year Restricted stocks vest over an average vesting period. Stocks vest only if the company is in operation.


Percentage of Employee Options[vendor]=Cumulative Employee Options[vendor]/Total Shares Outstanding[vendor]*100 % Dimensionless

Total Employee Shares Outstanding from Exercised Options[vendor]=SUM(Employee Shares Outstanding from Exercised Options[vendor,department]) shares
Total Employees[vendor] = SUM ( Rookie Employees[vendor,department!] + Experienced Employees[vendor,department!] ) ~ People

Cumulative Employee Options[vendor] = SUM ( Non Vested Employee Options[vendor,department!] ) + SUM ( Vested Employee Options[vendor,department!] ) ~ shares ~ The sum of the options, vested and non vested, held by employees of all types.

Options Exercised[vendor,department] = Fraction of Options Exercised[vendor,department] * Vested Options Reaching Expiration Date[vendor,department] ~ shares/Year ~ Employees exercise a fraction of their vested options approaching their expiration date.

Switch for Options = 1 ~ Dimensionless [0,1,1] ~ Switch = 1 firm gives out options to both new and existing employees, 0 otherwise.

************************************************* ****** *** ***********

.Stock Grants

************************************************* ****** *** ***********~

Cost of Repurchased Employee Shares per Employee[vendor, department]=Stock Price[vendor]*Repurchased Employee Shares per Employee[vendor,department] ~ $/(Year*People) ~ Costs of buying back employee shares per employee.

Employee Shares Exiting[vendor, department]=Total Quit Rate[vendor,department]*Shares per Employee[vendor,department] ~ shares/Year ~ When employees quit, they take their vested stocks with them and become non-employee owner of the shares assuming the company does not buy them back.

Former Employees[vendor, department]= INTEG (Experienced Layoff Rate[vendor,department]+Experienced Quit Rate[vendor,department]+Rookie Layoff Rate[vendor,department]+Rookie Quit Rate[vendor,department],0) ~ People

Fraction of Repurchased Employee Shares Upon Termination[vendor]=0 ~ Dimensionless [0,1,0,1] ~ fraction of employee shares sold back to company upon leaving the company.

Repurchased Employee Shares per Employee[vendor, department]=ZIDZ(Repurchased Employee Shares[vendor,department], Total Employees per Department[vendor,department]) ~ shares/(Person*Year) ~ Annual repurchased shares from former employee per employee.

Shares per Former Employee[vendor, department]=ZIDZ(Former Employee Shares[vendor,department], Former Employees[vendor,department]) ~ shares/Person

Repurchased Employee Shares[vendor,department]=Employee Shares Exiting[vendor,department]*Fraction of Repurchased Employee Shares Upon Termination[vendor] ~ shares/Year ~ Number of employee shares sold back to company when employees leave the company.

Rookie Hire Rate[vendor,department]= ( Employee Vacancies[vendor,department] / Time to Fill Employee Vacancies[vendor, department] ) * ( 1 - Bankruptcy Switch[vendor] ) * Company in Operation Switch[vendor] ~ Persons/Year ~ Hire sales people based on how many vacancies have been created and the avg time to fill them
Total Quit Rate[vendor,department] = Experienced Quit Rate[vendor,department] + Rookie Quit Rate[vendor,department]

Initial Non Vested Stock Grants[vendor,department] = Total Employees per Department[vendor,department] * Stock Granted per Hire[vendor,department]

Non Vested Stock Grants[vendor,department] = INTEG (Stock Grants Awarded[vendor,department]-Non Vested Stock Grants Expiring[vendor,department]-Stock Grants Vested[vendor,department],Initial Non Vested Stock Grants[vendor,department])

Non Vested Stock Grants Expiring[vendor,department] = Non Vested Stock Grants per Employee[vendor,department] * Total Quit Rate[vendor,department]

Non Vested Stock Grants per Employee[vendor,department] = \( \text{ZID} (\text{Non Vested Stock Grants}[\text{vendor,department}], \text{Total Employees per Department}[\text{vendor,department}]) \)

Stock Granted per Hire[vendor,department] = \( \text{ZID} (\text{Target Value of Stock Grants for New Hires}[\text{vendor,department}], \text{Stock Price}[\text{vendor}] \) * \text{Switch for Stock Grants}


Stock Grants Awarded to Existing Employees[vendor,department] = Stock Granted per Existing Employee[vendor,department] * Total Employees per Department[vendor,department]

Stock Grants Awarded to New Hires[vendor,department] = Stock Granted per Hire[vendor,department] * Rookie Hire Rate[vendor,department]

Switch for Stock Grants = 1

Target Value of Stock Grants for New Hires[vendor,department] = 0

The target value of the option package for new hires. This is part of the compensation package for employees and is assumed constant throughout the simulation.
Shares per Employee[vendor,department] = ZIDZ ( Employee Shares[vendor,department] , Total Employees per Department[vendor,department] )
  ~ shares/Person
  ~ Average vested grants per employee is the ratio of total vested employees to employees (by department).

Cost Sharing Switch = 0
  ~ Dimensionless [0,1,1]
  ~ Whether there's a carbon policy or not that will effect competitor's prices

customer <-> vendor
  ~ Index

department : sales,engineer
  ~

featuretype : appropriable,nonappropriable
  ~

Firm : startup1,startup2,incumbent,none
  ~

nonstartup1: startup2, incumbent
  ~

Number of Firms = 3
  ~ DmnI
startup : startup1,startup2
  ~

Value of Stock Granted per Existing Employee[vendor,department]=Reference Total Compensation[department] * Stock Granted for Existing Employees as Percentage of Industry Compensation[vendor] / 100
  ~ $/(Year*People)
  ~ Dollar value of the direct shares granted to employees as part of the compensation.

vendor : startup1,startup2,incumbent
  ~ Index
  ~ The model tracks three competing companies.

*****************************************************
 .Stock Options
*****************************************************

Basis Point=10000
  ~ Dimensionless
  ~ A basis point is 1/100 of 1%.

Cumulative Options per Employee[vendor]=Cumulative Employee Options[vendor]/Total Employees[vendor] * shares/Person

Desired Options Pool Fraction=0.15
  ~ Dimensionless [0,1,0.01]

Indicated Time to Exhaust Options Pool=(1-Switch for Game)*Time to Exhaust Options Pool+Switch for Game*TIME STEP
  ~ Year


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Options Granted per Employee per Year as Basis Point of Shares Outstanding = MIN (Desired Options Granted per Employee per Year as Basis Point of Shares Outstanding, Remaining Basis Point for Granting Options per Employee per Year)

~ 1/Person/Year [0,100,1]
~ Options granted per employee per year calculated as the basis point of the total shares outstanding. This measure is used to make the options granted more meaningful (than the absolute number of options) as it compares relative to the total shares.

Options Pool Fraction = (Cumulative Employee Options + Total Employee Shares Outstanding from Exercised Options) / Total Shares Outstanding
~ Dimensionless

Percentage of Non Vested Options = SUM(Non Vested Employee Options, Cumulative Employee Options) * 100
~ Dimensionless
~ The fraction of non vested options among all outstanding options. Zero if there are no options.

Remaining Basis Point for Granting Options per Employee per Year = (Desired Options Pool Fraction - Options Pool Fraction) * Basis Point
~ Dimensionless

Remaining Basis Point for Granting Options per Employee per Year = Remaining Basis Point for Granting Options / MAX(1, Total Employees) / Time to Exhaust Options Pool
~ 1/(Person*Year)

Time to Exhaust Options Pool = 1
~ Year

Switch for Game = 0
~ Dimensionless [0,1,1]
~ 1 = game is on. Model takes inputs from game player.

Experienced Compensation = 0
~ $/(Year*Person)
~ The annual salary of an experienced employee. This is part of the compensation package for employees and is assumed constant throughout the simulation.

Average Life of Vested Options = 5
~ years
~ The average life of a vested option.

Average Strike Price of Vested Options = SUM(Total Basis of Vested Options, Vested Employee Options) / Vested Employee Options
~ $/share
~ The average strike price of vested options is the total of all strike prices divided by the number of vested options outstanding. Set to zero if there are no vested options.

Fraction of Options Exercised = IF THEN ELSE (Stock Price > Average Strike Price of Vested Options, 1, 0)
~ Dimensionless
~ Options are exercised only if they are in the money.

Indicated Repricing of Non Vested Options = MAX (0, Average Strike Price of Non Vested Options - Stock Price) / Time to Reprice Options
~ $/(Year*share)
~ If the firm finds its employees' options are underwater they can elect to reprice them to a lower strike price. Options are only repriced if the switch to reprice options is active and if they are underwater (that is,
if the current stock price is less than the average strike price). The adjustment time determines how quickly the firm reprices existing options.

**Indicated Repricing of Vested Options** \[\text{Vendor, Department} \]
\[= \max (0, \frac{\text{Average Strike Price of Vested Options} - \text{Current Stock Price}}{\text{Time to Reprice Options}}) \times \text{Year} \times \text{Share} \]
\[= \text{MAX} (\text{Vendor, Department}) \]

If the firm finds its employees’ options are underwater they can elect to reprice them to a lower strike price. Options are only repriced if the Switch to Reprice Options is active and if they are underwater (that is, if the current stock price is less than the average strike price). The adjustment time determines how quickly the firm reprices existing options.

**Initial Non-Vested Employee Options** \[\text{Vendor, Department} \]
\[= (\text{Total Employees per Department} \times \text{Options Granted per Hire}) \times \text{Year} \times \text{Share} \]

The number of nonvested options granted to each type of employee at the start of the simulation.

**Non-Vested Employee Options** \[\text{Vendor, Department} \]
\[= \integ (\text{Options Awarded} - \text{Options Vesting} - \text{Non-Vested Options Expiring}, \text{Initial Non-Vested Employee Options}) \times \text{Year} \times \text{Share} \]

The total number of non vested options held by employees. Increases as options are awarded; decreases as options vest or expire on the attrition of employees.

**Non-Vested Options Expiring** \[\text{Vendor, Department} \]
\[= \text{Non-Vested Options per Employee} \times \text{Total Quit Rate} \times \text{Year} \times \text{Share} \]

Non vested options expire when the employees holding them leave the firm. Each employee leaving reduces the stock of non vested options by the average number of non vested options per employee.

**Option Price Relative to Share Price** = 1
\[= \text{Dimensionless} \]

The ratio of the option strike price to the current share price. Options are issued at par (100% of the current share price).

**Options Awarded** \[\text{Vendor, Department} \]
\[= \text{Options Awarded to New Hires} + \text{Options Awarded to Existing Employees} \times \text{Year} \times \text{Share} \]

Options are awarded to each new hire and, potentially, to each continuing employee.

**Options Awarded to Existing Employees** \[\text{Vendor, Department} \]
\[= \text{Options Granted per Existing Employee per Year} \times \text{Total Employees per Department} \times \text{Year} \times \text{Share} \]

Each employee receives a certain grant of options each year.

**Options Awarded to New Hires** \[\text{Vendor, Department} \]
\[= \text{Options Granted per Hire} \times \text{Rookie Hire Rate} \times \text{Year} \times \text{Share} \]

Each new hire receives a certain number of options.

**Options Granted for Existing Employees as Percentage of Compensation** \[\text{Vendor} = \text{GAME} (0) \]
\[= \text{Dimensionless} \times [0, 100] \]

**Options Granted per Existing Employee per Year** \[\text{Vendor} \]
\[= \frac{\text{Shares Outstanding} \times \text{Options Granted per Employee per Year as Basis Point of Shares Outstanding}}{\text{Basis Point} \times \text{Year} \times \text{Person}} \times [0, 10000, 1000] \]

Options granted per existing employees is the total shares outstanding times the options granted per employee as basis point of shares outstanding. Dividing by 10,000 to convert the basis point measure.
~ shares/Person
~ Each new hire should receive options worth the Target Value. The current
share price is used to determine the number of shares awarded. Zero if the
share price is zero.

Options Vesting[vendor,department] = ( Non Vested Employee Options[vendor,department] / Vesting
Period[vendor,department] ) * Company in Operation Switch[vendor]
~ shares/Year
~ Options vest over an average vesting period. Options vest only if the company is in operation.

Percentage of Vested Options[vendor]=ZIDZ ( SUM ( Vested Employee Options[vendor,department] ) , Cumulative
Employee Options[vendor] )*100
~ Dimensionless
~ The fraction of vested options among all outstanding options. Zero if there are no options.

Repricing of Non Vested Options[vendor,department] = Switch to Reprice Options * Indicated Repricing of Non Vested
Options[vendor,department] * Non Vested Employee Options[vendor,department]
~ $/Year
~ If the firm finds the options of its employees are significantly
underwater, they can choose to reprice the options at a lower strike price.

Repricing of Vested Options[vendor,department] = Switch to Reprice Options * Indicated Repricing of Vested
Options[vendor,department] * Vested Employee Options[vendor,department]
~ $/Year
~ If the firm finds the options of its employees are significantly
underwater, they can choose to reprice the options at a lower strike price.

Strike Price of New Options[vendor] = Stock Price[vendor] * Option Price Relative to Share Price
~ $/share
~ Options are issued with a strike price set at a specified ratio to the current stock price.

Switch to Reprice Options = 0
~ Dimensionless [0,1,1]
~ Switch to enable repricing of employee options that are underwater. 1 means repricing is active.

Target Value of Options for New Hires[vendor,department] = 0
~ $/Person
~ The target value of the option package for new hires. This is part of the
compensation package for employees and is assumed constant throughout the simulation.

Time to Reprice Options = 1
~ years
~ The time period over which a firm will reprice employee options that are
underwater, if they elect to do so (if the Switch to Reprice Options is active).

Total Basis of New Options[vendor,department] = Options Awarded[vendor,department] * Strike Price of New
Options[vendor]
~ $/Year
~ The total basis cost of all non vested options increases by the product of
the strike price of each option and the rate at which options are issued.

Total Basis of Non Vested Options[vendor,department] = INTEGR( Total Basis of New Options[vendor,department] -
Total Strike Price of Options Vesting[vendor,department] - Total Basis of Options Expiring[vendor,department] -
Repricing of Non Vested Options[vendor,department] , Initial Non Vested Employee Options[vendor,department] *
Strike Price of New Options[vendor] )
~ $/Year
~ The total basis cost of all non vested options. The ratio of this stock to
the number of non vested options outstanding is the average strike price
of the non vested options. Increases as options are granted; decreases as
options vest, expire, or are repriced.

Total Basis of Options Exercised[vendor,department] = Options Exercised[vendor,department] * Average Strike Price of
Vested Options[vendor,department]
~ $/Year
~ Options are exercised by employees at the average strike price for all vested options.

Total Basis of Options Expiring[vendor,department] = Average Strike Price of Non Vested Options[vendor,department]
* Non Vested Options Expiring[vendor,department]
~ $/Year
~ Options expiring reduce the total basis cost of all non vested options by
the average strike price.

Total Basis of Vested Options[vendor,department] = INTEG( Total Strike Price of Options Vesting[vendor,department] -
Total Basis of Options Exercised[vendor,department] - Total Basis of Vested Options Expiring[vendor,department] -
Repricing of Vested Options[vendor,department] , Vested Employee Options[vendor,department] * Strike Price of New
Options[vendor] )
~ $
~ The total cost basis of all vested options. The ratio of this stock to the
number of vested options outstanding is the average strike price of the
vested options. Increases as options are vested; decreases as options are
exercised or repriced.

Total Basis of Vested Options Expiring[vendor,department] = Vested Options Expiring[vendor,department] * Average
Strike Price of Vested Options[vendor,department]
~ $/Year
~ The total basis cost per year of the vested options that expire.

Total Strike Price of Options Vesting[vendor,department] = Options Vesting[vendor,department] * Average Strike Price
of Non Vested Options[vendor,department]
~ $/Year
~ Options vesting are assumed to be priced at the average strike price for non vested options.

Value of Options Granted per Existing Employee[vendor,department]=Experienced Compensation[vendor,department]
* Options Granted for Existing Employees as Percentage of Compensation[vendor] / 100
~ $/(Year*People)

Vested Employee Options[vendor,department] = INTEG( Options Vesting[vendor,department] - Options
Exercised[vendor,department] - Vested Options Expiring[vendor,department] , 0)
~ shares
~ The number of vested options increases as non vested options vest and
decreases when these options are exercised or expire.

Vested Options Expiring[vendor,department] = ( 1 - Fraction of Options Exercised[vendor,department] ) * Vested
Options Reaching Expiration Date[vendor,department]
~ shares/Year
~ Vested options reaching their expiration date that employees choose not to exercise expire.

Vested Options per Employee[vendor,department] = ZIDZ ( Vested Employee Options[vendor,department] , Total
Employees per Department[vendor,department] )
~ shares/Person
~ Average vested options per employee is the ratio of total vested employees
to employees (by department).

Vested Options Reaching Expiration Date[vendor,department] = Vested Employee Options[vendor,department] / Average Life of Vested Options[vendor]
~ shares/Year
~ The rate at which vested options reach their expiration date depends on
the number of options and their average life.
Effect of Learning Curve on Unit Cost\[vendor\]=(Cumulative Purchases[vendor] / Reference Production for Initial Cost)

\[ Unit Cost \]

Sensitivity of Unit Costs to Experience
~ Dimensionless

Cost Adjustment Fraction Due To Policy = 1 + ( Subsidy Policy Switch \* RAMP ( Subsidy Policy Effect on Cost / Subsidy Policy Ramp Time , Subsidy Policy Start Time , ( Subsidy Policy Start Time + Subsidy Policy Ramp Time ) ) )
~ Dimensionless
~ If there's a subsidy policy, then effect on our cost will ramp up to it's full effect starting at start time and taking the amount of time specified by ramp time.

Initial Unit Cost[startup]=61538
Initial Unit Cost[incumbent]=Initial Incumbent Unit Cost
~ Dollars/Unit

Effect of Functionality on Operating and Maintenance Costs\[vendor\]=[Feature Value[vendor]/Initial Feature Value[vendor]]^\text{Sensitivity of Effect of Functionality on Operating and Maintenance Costs}
~ Dimensionless

Initial Operating and Maintenance Costs=2400
~ $/Year/Unit

"O&M Cost Reduction per Doubling of Features"=0.5
~ Dimensionless
~ The reduction in the operating and maintenance costs of the product per doubling of features. The larger this is, the faster O&M costs fall as the features and functionality of the product improve.

Sensitivity of Effect of Functionality on Operating and Maintenance Costs = LN ( 1 - "O&M Cost Reduction per Doubling of Features" ) / LN ( 2 )
~ Dimensionless
~ The unit operating and maintenance costs of the product falls with feature development. O&M costs fall according to a standard learning curve.

Initial Feature Value[vendor] = Initial Features per Type[vendor,nonappropriable] \* Nonappropriable Feature Multiple + Initial Features per Type[vendor,appropriable]
~ Features
~ Total values of initial features.

Cost Reduction per Doubling of Experience=0.025
~ Dimnl
~ Fractional decrease in costs to produce the products per double the amount produced (i.e. sold)

Cumulative Purchases[vendor]= INTEG (Purchase Rate[vendor], Reference Production for Initial Cost)
~ Unit
~ Total number of purchases made (regardless of how purchases used)

Reference Production for Initial Cost=5
~ Unit
~ Initial Cost is assuming already produced this many of product

Sensitivity of Unit Costs to Experience = LN ( 1 - Cost Reduction per Doubling of Experience ) / LN ( 2 )
~ Dimensionless
~ Following standard learning curve theory, the exponent in the learning curve is set so that there is a given fractional cost reduction per doubling of cumulative production experience.

Share of Installed Base[vendor] = ZIDZ ( Cumulative Purchases[vendor] , SUM ( Cumulative Purchases[vendor!] ) )

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**Dimensionless**

~ Our installed base as a share of total industry installed base.

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### Venture Capital

Effect of Existing Sales on VC Willingness to Invest = Function for VC Willingness to Invest Due to Existing Sales (Installed Base/Reference Installed Base)
~ Dimensionless

Effect of Founder Ownership on VC Willingness to Invest = IF THEN ELSE [Percentage of Founders Ownership < Minimum Founders Ownership for VC Investing, 0, 1]
~ Dimensionless

Estimated Profit per Unit = 10000 $/Unit
~ $/Unit

Estimated Total Profit = Potential Market Size * Estimated Profit per Unit
~ $

Flush of VC Decision Switch Stock = IF THEN ELSE [VC Decision Switch = 1, VC Decision Switch Stock / TIME STEP, 0]
~ Dimensionless

Function for VC Willingness to Invest Due to Existing Sales:
- \((0.0,0.4)-(10,1)\)
- \((0,0.5),(1,0.5),(1,0.75),(2.5,0.88),(5,0.95),(10,1)\)
~ Dimensionless

Before the first sale, VC's willingness to invest low and only based on the potential market size. Once the startup has its first sales, VC's willingness increases gradually as the install based accumulates, showing confidence on the marketability of the products.

Increase in VC Decision Switch Stock = 1
~ Dimensionless

Inv5 Amt = 0
~ $ [0, le+007, 500000]

Inv5 Time = 4 Year
~ Year

Maximum Potential VC Net Worth = Market Capitalization * Maximum VC Ownership VC Willing to Invest / (1 - Maximum VC Ownership VC Willing to Invest)
~ $

Maximum VC Ownership VC Willing to Invest = 0.9
~ Dimensionless [0, 1]

Maximum VC ownership that VC is willing to invest. Once this is reached, VC will no longer invest in order to give the managers incentive to stay working for the company.

Minimum Founders Ownership for VC Investing = 10
~ Dimensionless

Potential VC Financing from Market Opportunity = Estimated Total Profit / Required Factor of Return
~ $

Proportion of Feasible VC Financing Effort by Department = 
\(ZIDZ(\text{Feasible VC Financing Effort by Department}, \text{SUM(Feasible VC Financing Effort by Department)})\)
Reference Installed Base=1
~
Unit

Required Factor of Return=10
~
Dimensionless

Switch for Adequate VC Financing Effort[vendor]=IF THEN ELSE(SUM(Feasible VC Financing Effort by Department[vendor,department])<Required VC Financing Effort[vendor], 0, 1)
~
Dimensionless
~
0 if there is inadequate VC financing effort when feasible is less than required effort.

Time for VC Application=1.5
~
Year [?;?;0.25]
~
The time it takes to go from the start of VC application date to the VC decision date.

VC Decision Switch[vendor]=IF THEN ELSE ( VC Decision Switch Stock[vendor] >= Time for VC Application , 1, 0)
~
Dimensionless

VC Decision Switch Stock[vendor]= INTEG (Increase in VC Decision Switch Stock[vendor] - Flush of VC Decision Switch Stock[vendor],0)
~
Year

VC Investment Climate=1
~
Dimensionless [0,2,1]
~
An exogenous index of investment climate signaling the macroeconomic conditions and availability of VC funding. 0 means a depressed market with no VC investing. 2 means a booming market with many available funding.

~
Dimensionless
~
VC willingness to invest = 1 when potential market size > than the minimum market size acceptable to VC and when firm has good enough technology such that its payback period < minimum payback period required by VC.

Maximum Payback Period for Customer Consideration=10
~
Year
~
Maximum payback period before customers start considering the product. Customers will not buy the product for any period greater than this.

Payback Period[vendor]=Inv2 Time/Price After Subsidy[vendor]-Price[incumbent], MAX(0, Energy Cost Savings[vendor]-Annual Service Fee per Unit[vendor]), Infinity)
~
Year
~
Payback period for customer = (Startup Price - Incumbent Price) / (Energy Cost Savings - Service Fee)

Follow On Investments[vendor]=Inv2 Amt[vendor]/TIME STEP * PULSE ( Inv2 Time , 0) + Inv3 Amt[vendor]/TIME STEP * PULSE( Inv3 Time , 0) + Inv4 Amt[vendor]/TIME STEP * PULSE ( Inv4 Time , 0) + Inv5 Amt[vendor]/TIME STEP * PULSE ( Inv5 Time , 0)
~
Dollars/Year
~
Investments made after the initial investment

Inv2 Amt[vendor]=4e+006
~
$ [0,1e+007,500000]

Inv2 Time = 1
~
Year [0,200,0.0002]

Inv3 Amt[vendor]=0
$O,le+007,500000$

Inv3 Time = 2
~ Year

Inv4 Amt[vendor]=8e+06
~ $O,le+007,500000$

Inv4 Time = 3
~ Year

Installed Base[vendor] = Total Prospects and Adopters by Firm[vendor] * Unit Purchased per Adopter
~ Unit
~ Total installed base of product in the market, calculated as total adopters multiplied by unit purchased per adopter. Note that the total adopters of each vendor includes those who have adopted but are considering switching to another vendor. Until they do, they remain customers of their current vendor, hence the installed base includes adopters and the total number of adopters of each vendor who are in the prospect chain while considering a switch to another vendor.

Indicated Adopters = Total Population * Addressable Fraction of Population
~ Prospects
~ This is the total addressable market size.

Unit Purchased per Adopter = 1
~ Units/Prospect $[0,20,2e-005]$
~ Average number of units each adopter purchases/uses at a time

Desired Years of Runway[vendor]=5
~ Year
~ Desired years of runway used for calculating the financing required from VC.

Available VC Financing[vendor]=IF THEN ELSE[Expected Present Value of Profit[vendor]>0, Potential VC Financing from Market Opportunity[vendor]*Effect of Existing Sales on VC Willingness to Invest[vendor]*VC Investment Climate, 0]$
~ $\$
~ Available VC financing is determined by the Potential VC Financing driven by potential market size times the effect of existing sales (as more sales increases willingness to invest) times Investment Climate which indicates the macroeconomic conditions.

Experienced Work Effort Net of Grantseeking[vendor,department]=Experienced Effective Work Effort[vendor,department] - Grantseeking Effort by Department[vendor,department]
~ Persons*Hours/Year
~ Work effort from experienced employees after subtracting coaching effort and grantseeking effort. It is assumed that coaching and grantseeking take precedence before work effort on VC financing, product development and sales.

~ Person*Hours/Year
~ Feasible VC financing effort from experienced sales and engineers.

Maximum Allowable VC Financing[vendor]=MAX(O, Maximum Potential VC Net Worth[vendor]-VC Net Worth[vendor])$
~ $\$
~ Maximum VC financing a VC will invest is what is remaining before VC reach the maximum VC ownership share.

Maximum Fraction for VC Financing Effort = 0.9
~ Dimensionless $[0,1]$
~ Maximum fraction of work effort from sales and engineers to work on VC
financing. A high value represents the firm is willing to abandon other
efforts to devote to VC financing, a possibility when the firm is running out of cash.

Minimum Market Size for VC Financing=1250
~ Unit
~ Minimum market size for VC to consider as worthwhile investment.

Potential Market Size[vendor]= (Indicated Adopters - SUM (Adopters[vendor!])) * Unit Purchased per Adopter
~ Unit
~ Potential market size is what VC considers whether to invest or not. It is
the total prospects minus the existing adopters, times the unit per adoptor.

Required VC Financing Effort[vendor]= VC Financing Asking Amount[vendor] * VC Financing Effort per Dollar * Switch
for VC Financing[vendor]
~ Person* Hours/Year
~ Desired VC financing effort is determined by financing needed and effort
needed to raise each VC dollar.

Switch for VC Application Period[vendor]= IF THEN ELSE ( VC Financing Asking Amount[vendor] > 0, 1, 0) * (1-Switch to
Allow Secondary Sales[vendor]) * Switch for VC Financing[vendor]
~ Dimensionless [0,1]
~ Switch for VC application date is on when financing required is positive,
i.e. firm starts applying for VC funding the moment it has financing
needs which itself depends on the desired cash coverage. It is turned off
after IPO when Switch for Allow 2nd Sales = 1.

Switch for VC Financing[vendor]=O
~ Dimensionless [0,1]
~ Switch to allow the possibility of VC financing.

VC Financing Effort by Department[vendor,department] = Switch for VC Application Period[vendor] * MIN ( Required
VC Financing Effort by Department[vendor,department] , Feasible VC Financing Effort by
Department[vendor,department] )
~ Person* Hours/Year
~ VC financing effort from each department is the lesser of the desired and
the feasible effort, effective only during the VC application period.

VC Financing Effort per Dollar=0.001
~ Person* Hours/Year/$
~ VC financing effort needed per VC dollar amount.
REFERENCE


June: 291-314.


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