Chapter 8: Uncertainty, Innovation, Entrepreneurship, and Progress

I. Introduction: Strategies for Coping with Uncertainty

Knightian uncertainty exists in choice settings in which unanticipated "shocks" may disrupt their plans. They may do so by subjecting individuals to less attractive or more attractive new circumstances. Individuals may be entirely surprised by them or know that such shocks are possible and take such possibilities into account when making plans. Such shocks may be generated by natural events such as earthquakes, volcanic eruptions, pandemics, or significant changes in weather. Or, they may be generated by human activities such as innovation and various kinds of campaigns that are intended to be surprise events for most or all of their intended targets.

In the first case, unanticipated shocks have no effect on individual choices—because individuals do not take such possibilities into account when making plans. Such unanticipated events are simply "things that happen," and after they happen, circumstances change, and individuals adjust to the new circumstances as well as they can. Their budget constraints may be simply a bit different or radically altered, or relative prices may be slightly or radically altered, and entirely new products or risks may subsequently be taken into account. After a surprise event has occurred, only the consequences of such events are relevant for analyzing the way such persons behave in the new circumstances. After the fact, they may remain oblivious to the possibility of future surprises. The models worked out in previous parts of this book would remain entirely relevant for such individuals.

Alternatively, past experience with surprise events may lead individuals to take them into account. This cannot be done perfectly, because the nature of a surprise is that it cannot be fully anticipated. Nonetheless, although the details and timing of surprise events remain unknown, individuals may take in to account the possibility that such "unknowable shocks" are possible. Plans that take such possibilities into account may do so in a variety of ways, as developed in this chapter. For "surprise anticipating" individuals, the mere possibility of surprises affects behavior. Some of that behavior tends to reduce the effects and frequency of unpleasant surprise events and other may attempt to increase the effects and frequency of pleasant surprises.

II. Rainy Day Funds and Lines of Credit as Methods for Coping with Uncertainty

Surprise events can be generated both by the unknowable or by the knowable, but presently unknown. For example, geologist use the notion of "100-year floods" when they analyze the erosion caused by rivers and oceans. Such floods are severe ones that occur roughly every century. A thousand-year flood is even more intense and rare. Persons purchasing land in a 100-year or 1000-year flood plain may be unaware of or ignore such rare events when assessing the value of a particular piece of property. They do so by ignoring or "truncating" their assessment of risks by leaving "outliers" outside their expected value calculations. They may for example only account for risks that occur every ten years or less. Alternatively, there may be events that are totally beyond the imagination or knowledge of such persons—a meteor crash, rare earthquake, or cycle in the lives of termites—which may reduce the value of their investments in a way that is entirely unknown to them rather than simply ignored.

Both such sources of residual uncertainty have similar effects on the plans made—their plans fail to take account of all relevant possibilities and so tend to be error prone. Surprises are possible in either case.

Nonetheless, persons that have experienced unpleasant surprises in the past may take steps to mitigate the downside risks associated with such events when the losses associated with them are nontrivial. One method of doing so is to accumulate reserves that can be used to mitigate the losses associated with a wide variety of such unpleasant surprises. Cash and bank accounts can serve this purpose. Cash can be used to mitigate the losses associated with a wide variety of unpleasant surprises by providing resources to cope with them. For example, one's home may be flooded by a 100-year flood, but one may have set aside sufficient cash reserves to stay in a hotel or rent an apartment, while one's under water residence is rebuilt or to begin shopping for another abode on higher ground.

Notice that, whether the event is unknowable or simply unknown does not affect the problem faced by the individual when trying to decide how large of a reserve to hold. He or she does not know the probability of the "negative shock," nor its magnitude. (The house may well survive a neglected 50-year flood but not a 100-year flood.) One may use the logic of expected value calculations by imagining probabilities for surprise events, but those values are not likely to reflect the actual probability of the event—even if they do make the calculation of reserves more systematic.

Another strategy that can be used when the phenomena generating the surprises is thought to be probabilistic, but the relevant probability distribution is simply unknown to individuals or to humankind. Individuals or groups may undertake research to learn the relevant underlying probably functions, and then use those functions to determine optimal reserves if insurance is not available—or perhaps found companies that could sell such insurance.

However, time is a scarce resource for all individuals and organizations, and thus obtaining such knowledge may be too expensive to undertake. (Remaining ignorant of many details can be a completely rational strategy.) And, of course, it may turn out that such phenomena are not amenable to probability theory. Thus, the gathering of information about surprise events is itself a decision that tends to be conducted with Knightian uncertainty. What is not known now but potentially knowable, obviously, cannot be known beforehand.

Fortunately, the surprises generated by such uncertainty includes pleasant surprises as well as unpleasant ones.

III. Some Historical Context

Neoclassical economics assumes perfect predictability and stability in the markets used to explain market prices. Firms attract and retain their labor forces and ongoing contractual relationships with other input providers and are well aware of other potential input providers that could be used. Consumers, likewise, have continuing relationships with firms from whom they buy or potentially may purchase their goods and services from. It is such continuing relationships that make the informational assumptions of neo-classical economics plausible. In such cases, firm owners and managers will know input prices and consumers the prices of outputs.

In the neoclassical models of part I of this book, capital accumulation was the main possible engine of economic development. Growth takes place as capital is accumulated, but only to the point where new capital equals the rate of depreciation (Solow 1956). In the resulting very stable market settings, market relationships are continuing and, in a sense, long term ones under which consumers and firms repeat their pattern of production and purchase every year. Minor refinements in tastes and production methods may occur, but the economy generally takes the form of an evenly rotating economic system. Wages and rental payments to input providers provide the income necessary to demand exactly what is produced in all the markets frequented by consumers. Essentially the same products are produced in the same manner every year. The effects of any stochastic phenomena are well known, and addressed through various insurance-like products, as discussed by Knight.

Most of these assumptions were consciously made when neoclassical economics first emerged as a coherent method of understanding market prices and sources of income. They were simplifying assumptions that made the logic, geometry, and mathematics of markets tractable and their implications clear. They described how complex networks of exchange and production operate in stable circumstances. Decisions throughout the networks are coordinated by market prices (Hayek, 1945) and so no over-arching information about the economy as a whole is necessary for its equilibria to emerge and be stable.

The assumption of stable market relationships was plausible when classical economic emerged in the late eighteenth century and early nineteenth century, but they were somewhat less reasonable in the period in which neoclassical economics emerged in the late nineteenth century and early twentieth century. Prior to 1800, the core of the Western product mix had not changed very much for centuries. Most persons were employed in agriculture. Most products were locally made and not very different from the ones made in the previous century or so. One would often personally know the merchants and tradesmen that one purchased goods and services from. By the late nineteenth century, in contrast, significant innovations had emerged. Many long-standing commonplace goods were being produced in new ways. Such changes, however, may be less than obvious insofar as relatively little would be known about them outside the mines and buildings in which production took place. Nonetheless, by the late nineteenth century and early twentieth century. there were many entirely new goods and services brought to markets such as rail transportation, the telegraph, telephone, electric lighting, bicycles, and cameras.

For example, in the late eighteenth and early nineteenth century, clothing went through cycles of fashion, but that the production of cloth for those cloths was increasingly automated and propelled by wind, water, and steam. Such innovations made little difference to consumers except insofar as the cost of clothing fell, freeing their income for other purposes. Such changes were often adopted slowly as rival firms figured out how the occasional innovator managed to produce similar products more quickly amd cheaply than they could.

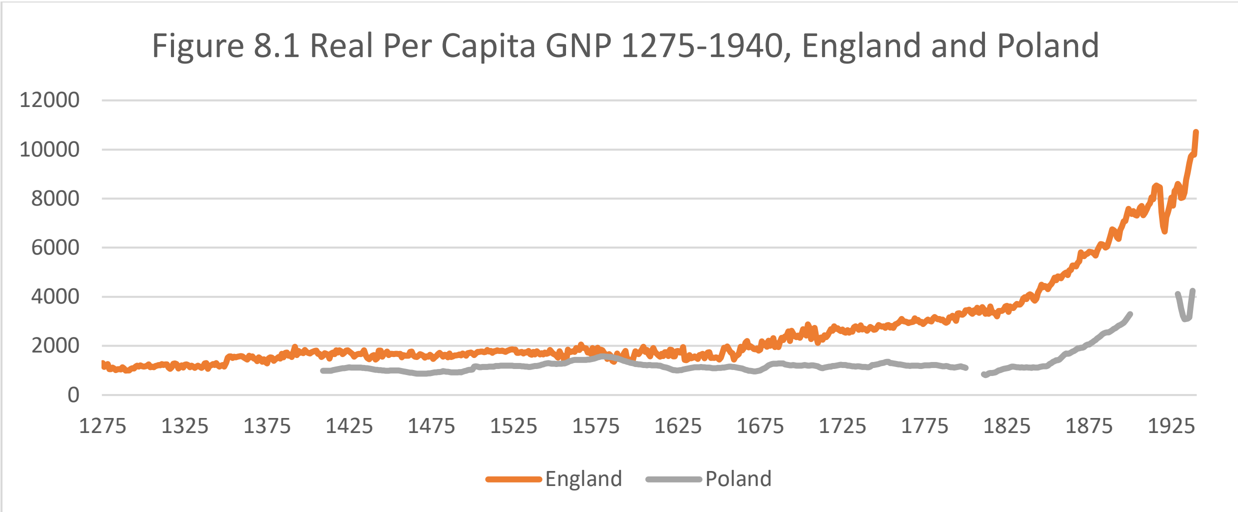
However, this was less true during the second half of the nineteenth century, as many entirely new products and services were brought to market. The railroad was more than a better horse-drawn stagecoach. The lightbulb was more than a fancy candle. The steam ship was more than a new type of sailboat. The automobile and airplane were new modes of transportation not simply enhancements of the old ways, which had relied on animal muscle power for millennia. Telegraphs and telephones were not simply faster letters. Photographs, plumbing, and washing machines were not simply new forms of paintings or methods of delivering water, disposing of wastes, or cleaning one's attire.

Moreover, the new and improved production methods often required far larger organizations, investments, and markets to take advantage of than their traditional counterparts. And, although there had been rich people for thousands of years, they were mostly persons that owned or controlled large pieces of land. In the nineteenth century, the persons that created new organizations to produce new services in new ways often became rich. At first, they were looked down on by the wealthy landowner class and chided for being "capitalists" or grubby "industrialists." But gradually, those landowners either also became capitalists or they gradually faded into the background as their lands were bought up by successful entrepreneurs.

During the late nineteenth century, innovation became routine, in part, because innovation turned out to be a very profitable activity. There were many areas of life in which unrealized gains from innovation, new production methods, and new products could be realized. And fortunes were often—although not always--amassed by doing so.

As a consequence, markets activities became much less stable. New products could displace older products that had existed for hundreds of years—as electric lights replacing candles (and candle makers) and automobiles replaced horse and buggies (and buggy manufacturers) and gas stations replace feed stores, and so on. Certainty diminished and uncertainty increased—yet the overall effect was a more prosperous society. Average income and longevity increased—and the entire process accelerated during the late nineteenth and twentieth centuries.

Economic growth was no longer just a matter of capital accumulation but of new forms of capital, new products, new forms of economic organization, and constant innovation.



(This figure is based on one included in chapter 13 of Congleton (2022). Note that by the time that Poland's economic development began to accelerate, that RGNP per capita in England was approximately four times as large as that in Poland.)

Although this period of accelerating commerce was well underway by the time that neoclassical economics emerged, theories of innovation did not find its way into neoclassical models or textbooks. This was not a factor of economic development that could be ignored in the twentieth century (although they were by in large), because so much of economic growth involved the introduction of entirely new products and services, often produced in entirely new ways—ways that a few decades earlier would have been widely regarded as impossible, as with air travel, radio broadcasts, antibiotics, and television.

IV. Theories of Innovation and Entrepreneurship

Innovation is possible because of gaps in human knowledge—the possibility of pleasant surprises as well as unpleasant ones. One may attempt to discover such surprises, as with a pleasant walk that one might take in the Spring with the hope of seeing early flowers or returning birds. One may not know that any are "there" to be seen, but one may take a walk because they may well be there as Spring emerges from Winter. Pleasant surprises may occur or not from such walks. Similarly, one may believe that it is possible to use wind or water power to saw boards or make cloth from thread, and willing to gamble some resources on projects to see whether or not it truly is possible or not? If one guesses correctly, the result may be a new easier way to produce lumber or cloth and profits associated with them. In effect, both these activities are the opposite of rainy-day funds. They use, rather than conserve, resources to make a pleasant surprise more likely to be experienced—rather than an unpleasant one less likely to be experienced.

In neither case, could one accurately describe a probability function that describes the phenomena sought or avoided. Although, one can use statistical types of statements to describe one's thought process. The "probability" of success, however, is does not describe a process with a stable frequency distribution, but rather one's confidence in a guess or intuition about whether some positive or negative surprise may occur—if one undertakes particular activities. It is gaps in knowledge that one hopes to exploit as an innovator—and gaps in knowledge that one hopes to avoid losses from in the case of crisis management. In neither case does one know exactly what one will discover—and in both cases, it is quite possible that nothing extraordinary will happen. Potential innovators often fail, just as rainy-day funds may prove inadequate for an emergency or crisis that emerges.

One of the innovations of the nineteenth century was that innovation itself can be systematically sought, even if one does not truly understand the "odds" of success or exactly what success entails. Innovation factories emerged in the late nineteenth centuries, among which that of Thomas Edison is among the most famous in the United States.

Although neoclassical-based textbooks rarely give innovation much attention, this is not because there are no theories of the impacts or explanations for innovation. As a rule, the theories attribute innovation to "entrepreneurs," who are often, but not always, regarded to be a bit special in their capabilities and attitudes toward risk. This section of chapter 8 provides short overview of four theories of entrepreneurship. The sections that follow provide models of their activities.

Frank Knight: Entrepreneurs as "Risk" Takers

> It is evident that if the laws of economically significant changes are known, those human actions which give rise to such changes will be governed by the same motives as the operations productive of immediate utilities, and in the competition of resources for profitable employment returns will be adjusted to equality between the two fields of use. …
>
> Dynamic changes give rise to a peculiar form of income only in so far as the changes and their consequences are unpredictable in character. Knight, Frank. *Risk, Uncertainty, and Profit* (p. 18). (Kindle Edition.)

Knight regards entrepreneurial profits to be results of "gambles" where the odds cannot be known beforehand—which is to say circumstances of Knightian uncertainty. Entrepreneurs who profit form innovation or other forms of speculation are simply luck risk-takers from this perspective. If enough low-probability gambles are undertaken someone will win their bet and profit by discovering and introducing a new product or form of innovation. After all, some one always wins a lottery. Some persons may win more than once, just as one could roll two dice and come up with 7 or some other number ten times in a row, if one rolled the dice long enough.

However, Knight insists that it is uncertainty rather than risk that generates the profits, because if the odds were known before hand, it would be undertaken in a manner consistent with expected utility or expected profit maximizing calculations and therefore, if a sufficient number of persons invested in such strategies, the returns would fall to the normal rates of return (possibly adjusted for risk in the absence of insurance markets for the relevant activity). From Knight's perspective, entrepreneurs differ from ordinary persons only insofar as they are willing to invest in projects with unknown returns—they are risk takers, not in the sense of taking well-understood gambles, but in the sense that they are willing to trust their intuition about returns that cannot be reduced to probabilities in the sense of well understood frequency distributions.

Joseph Schumpeter, Entrepreneurs as Insightful Disruptors

> **These revolutions periodically reshape the existing structure of industry** by introducing new methods of production—the mechanized factory, the electrified factory, chemical synthesis and the like; new commodities, such as railroad service, motorcars, electrical appliances; new forms of organization—the merger movement...
>
> Every piece of business strategy acquires its true significance only against the background of that process and within the situation created by it. It must be seen in its role in the **perennial gale of creative destruction**; it cannot be understood irrespective of it or, in fact, on the hypothesis that there is a perennial lull (Schumpeter, J. [1942/2012], *Capitalism, Socialism, and Democracy* [KL 1519–1521, KL 1844–1847]).

Josephy Schumpeter was doing his research during the same period as Frank Knight, but rather than focus on risks and uncertainties associated with commercial societies as they had emerged in the early 20th century, was more interested in the innovators and innovations themselves and how they affected market equilibria. He was one of the first economists to argue that innovation is the main source of economic development. His approach did not catch on within the mainstream economics until towards the end of the 20th century. Models rooted in the core neoclassical models continued to be dominate textbooks and journals—and still do outside the relatively small group of economists that focus on innovation. (See CH Tzeng, 2008, for a survey of the late 20th century literature on innovation.)

Schumpeter first books in this area were written in German and attracted little attention outside the German speaking world of the former Holy Roman Empire of central and northern Europe. His theory of economic development was written in 1934, but not translated into English until 1961—although Schumpeter himself could have done so if he wished, since he moved to the United States and taught at Harvard for two decades shortly after the book was published. A shorter simplified version of his theory was included in his more widely read book *Capitalism Socialism and Democracy* (1942).

According to his theory, in the absence of innovation, markets reach equilibrium and remain stationary circular flow systems—analogous to the implications of a Walrasian equilibrium with a steady state supply of capital and labor. In this, his point of departure is similar to that of Knight's. However, according to Schumpeter, innovation disrupts the preexisting equilibrium—sometimes radically so—and usually generates additional sources of welfare, as new products are introduced, or new more efficient (less resource intensive) methods of production are adopted.

From the Schumpeterian perspective, entrepreneurs are unusually creative men and women who bring entirely new products or production processes to market and thereby disrupt a previously existing pattern of economic organization. They are human outliers in terms of their ability to perceive profitable new opportunities and bring them to markets. Although it is clear that without imperfect information, such opportunities would not exist, Schumpeter's entrepreneurs are able to perceive opportunities more clearly than others and so profit from their unique insights, persistence, and organization.

Although Schumpeter seems to focus much of his attention on major innovations—disruptive innovations—the same could be said about refinements in preexisting devices, services and methods of production. Such less disruptive innovations also often require unusual insights (or luck) as well as persistence and organization.

In all of these cases, Schumpeter emphasizes the expansion of markets that go beyond the stable k-good worlds of general equilibrium models and other neoclassical models of market and social equilibria.

Israel Kirzner: Entrepreneur as and Equilibrator

> Much of our discussion will revolve around two notions crucial to an understanding of the market and central to its theory—competition and entrepreneurship. Both terms are widely used in the everyday speech of laymen concerning economic and business affairs. During the history of economics, a great deal has been written about these notions, and the first of the two has become the subject of an enormous literature. …
>
> The market process, then, is set in motion by the results of the initial market-ignorance of the participants. The process itself consists of the systematic plan changes generated by the flow of market information released by market participation—that is, by the testing of plans in the market. …
>
> The outcome is always the same: the competitive market process is essentially entrepreneurial. The pattern of decisions in any period differs from the pattern in the preceding period as market participants become aware of new opportunities. As they exploit these opportunities, their competition pushes prices in directions which gradually squeeze out opportunities for further profit-making. The entrepreneurial element in the economic behavior of market participants consists, as we will later discover in detail, in their alertness to previously unnoticed changes in circumstances… Kirzner, Israel M.. *Competition and Entrepreneurship* (pp. 10-16). University of Chicago Press. Kindle Edition.

Kirzner's approach to entrepreneurship is, in a sense, between those of Knight and Schumpeter. Such persons are especially alert to changes in circumstances that present new opportunities for profit—whether through speculation, the creation of new products, or the recognition of new modes of production. For Kirzner, in contrast to Schumpeter, such activities tend to be equilibrating in the sense that ignorance is reduced and opportunities that were latent in the setting of interest come to fruition rather than being left unrealized. In contrast to Knight, he suggests that such insights may be certain ones that simply are perceived more clearly or more rapidly than the insights of ordinary consumers and firms—who may also engage in entrepreneurial insights, but perhaps a bit more slowly and with less clarity. Ignorance—but not uncertainty—play a role in Kirzner's theory of entrepreneurship.

Kirzner's theory of entrepreneurs—e.g., of person who earn their livelihoods through a superior ability to recognize profitable opportunities when they emerge—thus implies, like

Schumpeter's that full-time entrepreneurs are a bit unusual—but outliers of a different sort than stressed by Schumpeter. Rather that unusually creative and persistent individuals, they are unusually alert and perceptive about opportunities that emerge in market settings as individual plans are adjusted to new information and unexpected surprises of various kinds. The end result of Kirznerian entrepreneurship is not disruption, but a smoothing of market adjustments that makes major innovations less disruptive than they would otherwise be—and also makes entrepreneurial activities far more commonplace than in the Schumpeterian notion of entrepreneurship—even if full-time entrepreneurs are also a bit special in Kirzner's assessment.

Entrepreneurs as Formeteurs

> All organizations can impose rules on their own team members because realizing the fruits of team production normally requires team members to perform certain tasks at particular times with particular persons in a particular manner. The range of behaviors that can be induced by organizations varies substantially, but many organizations exercise significant control over their members. An organization's management is often able to tell team members how to dress, when and what to eat, when and how to work, and even who their friends should be (other team members). The organization's management may induce team members to go on trips far away from families and friends (as with hunting clubs, commercial transport shipping, and military operations), via means and to settings that involve risks to life and limb.
>
> Very large, successful organizations are often created by energetic formeteurs, such as Henry Ford, Kiichiro Toyoda, Thomas Edison, Friedrich Krupp, Henry Dunant, Clara Barton, and the like. Such talented formeteurs can impose many rules on their team members, but relatively few rules on people outside their own organizations. Congleton. *Perfecting Parliament* (pp. 77, 81). Cambridge University Press. Kindle Edition.

The theory of organizations sketched out in Congleton 2011 focuses on a specific form of entrepreneurship, namely that associated with founding organizations. In Schumpeter's (1934) and Kirzner's (1978) terms, a formeteur creates, or recognizes organizational opportunities that others do not have or cannot see. Consequently, innovation, foresight, and boldness are often associated with organizational leadership along with an exceptional ability to recruit and motivate team members. Formeteurs may also be said to be less risk averse than others (Knight 1921) insofar as they are more willing to accept the risks associated with launching new enterprises. Formeteurs, however, differ from the entrepreneurs of classic economic models because they form organizations that solve a variety of team production problems. Innovative formeteurs create new systems of rules that make their organizations more productive than others that they know of.

This process when applied to economic organizations can be a source of profits as well as fame. They may simply improve the organization of production with respect to existing products or they may organize innovation itself, so that profitable many new products and methods are discovered and/or worked out that profit the organizations founded. Even Thomas Edison, as clever as he was, did not invent every product produced by General Electric himself. Rather, he created an organization that created and produced new products and methods for using electrical power using various forms of team production—many of which he and his team originated.

The famous entrepreneurs of history are rarely single inventors or speculators but generally were individuals who caused large profitable organizations to be created, and which were self-sustaining in the sense that they generated sufficient revenues to retain its employee-team members and sufficient profits to maintain the organizations founders and leaders in sufficient comfort that they were not tempted to move on to other ventures or organizations. Examples from the United States include Graham Bell, Thomas Edison, Henry Ford, Howard Hughes, Steven Jobs, Bill Gates, and Elan Musk to name just a few founders of large innovative and profitable organizations. Many others exist throughout out the world, and a significant subset of them were both founders of large commercial companies that were Knightian risk takers and Schumpeterian disruptors.

V. Two Choice Settings and Two Models of Entrepreneurship

All the above suggests that there are two choice settings First, there are settings of ignorance, where potentially knowable causal or probabilistic phenomena exist that are not understood by persons in the society of interest. In such settings, an entrepreneur may, by reducing ignorance, benefit from a clearer understanding of possibilities and probabilities than others and so at least temporarily profit from his or her (or his or her team's) insights. In such cases, it is ignorance rather than Knightian uncertainty that is the source of profits, as is often the setting that seems to be imagined by the last three theories of entrepreneurship. Second, there is Knightian uncertainty that is not a consequence of ignorance, per se, but of the underlying process that generates the choice setting or the consequences of choices. In such cases, what might be termed Knightian luck is more likely to be the dominant source of unusual profits. Both types of circumstances can be modelled.

Ignorance and Entrepreneurship

The first and most tractable setting for entrepreneurship is that characterized by Kirzner, where ignorance is a significant source of unrealized potential gains to trade—whether directly by causing particular well-understood products or methods of production to be under used or used inappropriately, or indirectly as when completely feasible technological innovations exist, but are presently unknown or unrecognized that allow new production methods and/or products to be profitably sold through commercial networks. Research and development activities—when appropriately focused and organized—can reduce ignorance and produce profitable innovations although not with certainty. Of course, an important part of the puzzle is how to organize and focus those efforts, but initially we'll assume that a insightful entrepreneur has organized a team and focused it on puzzles that can be solved through reasonably well-understood stochastic processes. These are not small assumptions and are more likely to be true for efforts to improve existing products and production methods than to invent entirely new ones.

Assume that the demand function for Acme's product is monotonically decreasing in price and monotone increasing in quality, Φ, $Q^D = q(P, \Phi)$. The quality of the product sold continues to be $\Phi = \Phi^0$ if R&D is unsuccessful and $\Phi = \Phi^0 + \Delta$ if it is successful. The probability of success increases with R&D expenditures, R, F = f(R), which implies that expected quality is $\Phi^e = f(R)(\Phi^0 + \Delta) + (1\text{-}f(R))\,\Phi^0$. The cost of producing the product is thus C=c(Q, R, w, r).

We can characterize Acme's output and R&D decision in a manner that is similar to a firm's investment in quality control that was analyzed in chapter 7. We'll assume that Acme's product is sufficiently different from others that it faces its own downward sloping demand curve. Because of this, we use the implicit function theorem to characterize Acme's inverse demand function, P=p(Q, Φ), then write down Acme's expected profit function, which in this case is affected by the probability of successful innovation. To simplify the notation a delta superscript is used to indicate the case in which innovation is successful and so demand for Acme's product is greater than it would otherwise have been.

$$\Pi^e = f(R)P^{\Delta}Q + (1 - f(R)PQ - C \qquad (8.1a)$$

Or equivalently, written out in more detail, as:

$$\Pi^e = f(R)p(Q, \Phi + \Delta)Q + (1 - f(R)\,p(Q, \Phi) - c(Q, R, w, r) \qquad (8.1b)$$

We'll assume that the expected profit function is strictly concave. In that case the ideal combination of investment in R&D and output levels can be characterized with two first order conditions. The first is a derivative with respect to output, Q, and the second is a derivative with respect to expenditures on research and development, R. The subscript notation for partial derivatives to reduce the number of terms that need to be written down.

$$\Pi_Q^e = f(R)[P^\Delta + P_Q^\Delta Q] + (1 - f(R))\left[P + P_Q Q\right] - C_Q = 0 \qquad (8.2a)$$

$$\Pi_R^e = F_R P^\Delta Q + (-F_R) P Q - C_R = 0 \qquad (8.2b)$$

Both these partial derivatives have to be satisfied simultaneously at R* and Q*.

There is a multi-equation version of the implicit function theorem that allows optimal values for each of the control variables to characterized as functions of the (exogenous) parameters of the choice setting. In this case, it implies that

$$Q^* = s(\Phi, \Delta, w, r) \qquad (8.3a)$$

and

$$R^* = e(\Phi, \Delta, w, r) \qquad (8.3b)$$

The values for prices and expected quality are determined by substituting these ideal values into those functions. Pricing is a bit tricky here, because of the uncertain quality, and could be adopted once it is known whether R&D was successful or not. Alternatively, for planning purposes, the price of the firm's output might be determined on the basis of expected quality.

Unfortunately for the present text, the implicit function differentiation method for systems of equations requires matrix methods that are beyond the scope of this text. Thus, comparative statics cannot be directly undertaken using this approach without additional matrix-based tools. Such tools are rarely used in contemporary research and so they are neglected in this textbook. There is, however, a substitution method that potentially allows comparative statics to be undertaken without matrix tools, as outlined below.

A Substitution Method for Fully Characterizing the Equilibrium Levels of Output and R&D without Matrix Methods

The substitution method that can do in cases where there are two control variables initially assumes that one of the two control variables is held constant, and then characterize ideal levels of the other. We'll hold R constant and characterize Q* in the usual way, but for a slightly more complex profit function.

The profit function is the same as before, as characterized by equation 8.1a. The first order condition of interest is the the same as the partial derivative with respect to output, Q (equation 8.2a).

$$\Pi_Q^e = f(R)[P^{\Delta} + P_Q^{\Delta}Q] + (1 - f(R)\big[P + P_Q Q\big] - C_Q = 0 \equiv \text{H} \ \text{ at Q*} \qquad (8.4)$$

(Subscripts again denote derivatives with respect to the variable subscripted, here Q.) The implicit function theorem allows this relationship to be used to characterize Q* as a function of parameters of Acme's choice setting. This is similar to equation 8.3a above but also includes R, the expenditure on R&D, because the choice setting first model assumes that R is constant thus a parameter of the choice setting rather than a control variable.

$$Q^* = s(\ R, \Phi, \Delta, w, r) \qquad (8.5)$$

We know from previous work that the implicit function differentiation rule can be used to determine the effects of changes in $R, \Phi, \Delta, w \ or \ r$ on the firm's output decision and thereby on its price. That method can also be used to determine the effect of R&D expenditures on Acme's output decision.

$$Q_R^* = \frac{H_R}{-H_Q} = \frac{f_R[P^{\Delta}+P_Q^{\Delta}Q] - f_R[P+P_Q Q] - [C_{QR}+C_R]}{-(\Pi_{QQ})} > 0 \qquad (8.6)$$

The term in the denominator is positive if the expected profit function strictly concave. The numerator is more complex. It is essentially the effect of R&D on expected marginal revenues and costs. As R&D expenditures increase, the first marginal revenue term increases and the second decreases, while marginal costs tend to rise. So, this effect depends in part on how much R&D is being undertaken. If R&D occurs in its profitable range at the margin, the numerator will be positive because its effects on marginal revenue in that range are greater than its effects on marginal cost. This is the relevant range for firms, which implies that the numerator is positive. Thus, the firm's output will increases as R&D expenditures increases—other things being equal—because greater R&D expenditures makes it increasingly likely that the quality of the product will increase in a manner that increases demand for the firm's product.

To determine the extent of R&D that maximizes profits, we substitute the function characterizing the ideal output level into the profit function and then differentiate with respect to R. That first order condition will characterize R* in a manner that takes account of all of its effects on the demand for the product and the cost of production. Once that is known, Q* will simply be $Q^* = s(R^*, \Phi, \Delta, w, r)$, P* = q(Q*, Φ^e), and Φ^e = f(R*)(Φ^0+ Δ) + (1-f(R) Φ^0. Comparative statics in turn can be undertaken at the level of R* and its impacts on all the other variables determined—at least in principle—using the single equation method that we've used many times in prior chapters.

The expected profit function is now written as:

$$\Pi^e = f(R)p(Q^*, \Phi + \Delta)Q^* + (1 - f(R)\, p(Q^*, \Phi)Q^* - c(Q^*, R, w, r) \quad (8.7a)$$

The simpler notation developed above, with P^Δdenoting $p(Q^*, \Phi + \Delta)$ and P denoting $p(Q^*, \Phi)$ again reduces somewhat the notational complexity of the derivative of interest, which characterized how expected profits change as R&D increase.

$$\Pi^e = FP^\Delta Q^* + (1 - F)\, PQ^* - C \quad (8.7b)$$

Differentiating with respect to R and setting the result equal to zero fully characterizes R* and the usual form of the implicit function theorem can be used to characterize R* as a function of the parameters of this choice setting. This characterization takes full account of how output and pricing adjustments are affected by R&D. The first order condition is thus a bit more complicated than the that of equation 8.2b.

$$\Pi_R^e = [F_R P^\Delta Q^* - F_R P Q^*] + F(P_Q^\Delta Q_R Q + P^\Delta Q_R) + (1 - F)(P_Q Q_R Q + P Q_R) - C_R = 0 \text{ at } R^* \quad (8.8)$$

The product rule is used on the first two terms of equation 8.7b both "outside" with respect to the probability functions (f(R)) and inside for the price times quantity relationships. The subscript notation again reduces the notational complexity of the derivative of interest.

The implicit function theorem implies that equation 8.8 serves as a basis for characterizing optimal levels of R&D expenditures, R*, as a function of the parameters of Acme's choice setting. The implied function closely resembles equation 8.3b, although in this case it takes full account of the effects of R&D on output levels through the Q* function.

$$R^* = g(\Phi, \Delta, w, r) \quad (8.9)$$

Given the ideal level of R&D expenditures, Acme's ideal output level is:

$$Q^* = s(\, R^*, \Phi, \Delta, w, r) \qquad (8.10)$$

And the associated expected price of its output is

$$P^* = q(Q^*, \Phi^e) \text{ and } \Phi^e = f(R^*)(\,\Phi^0 + \Delta) + (1\text{-}f(R)\,\Phi^0 \qquad (8.11)$$

Comparative statics of the R* function can be undertaken with the single equation form of the implicit function differentiation methods used in previous chapters.

Knightian Uncertainty and Entrepreneurship

The Knightian choice setting is more difficult—if not impossible—to model unless entrepreneurs use a though process similar to that above. Although they can only use probabilities and conditional probability functions that are intuitive guesses—because of a lack of experience with the innovation process necessary for success or simply because it is so complex that it cannot reliably be characterized with a probability function—entrepreneurs may find it useful to undertake an analysis similar to that above using their best guesses about the likelihood of innovation or profits from other speculative opportunities. For example, entrepreneurs may use guesses about the f(X) function—and whether R&D is undertaken or not would depend both on the factors worked out in the previous example, the entrepreneur's confidence in his or her guesses about the f(X) function, beliefs about how innovation will affect demand for the product of interest, and his or her risk aversion. Such decisions would also vary with the expected period in which sales would increase.

That confidence can be grounded in an entrepreneur's superior ability or access to relevant information (as in Schumpeter or Kirzner) or it may be grounded simply in what some term "entrepreneurial spirit," as in Knight's approach to entrepreneurship. Given intuitive estimates about intuitions or guesses about potential sales, profits, and the probability of success, the same analytics can be used to characterize firm/entrepreneur decision in cases of Knightian uncertainty as in the case analyzed in the previous section of this chapter. Because odds of success naturally tend to be lower when one knows less about the innovative process, naturally the failure rates would tend to be higher in such cases than in the "refinement" type of innovations modelled in the previous subsection.

According to the U.S. Bureau of Labor Statistics (BLS), failure rates are high, which would accord with the Knightian approach to entrepreneurship. Data from the BLS shows that approximately 20% of new businesses fail during the first two years of being open, 45% during the first five years, and 65% during the first 10 years. Only 25% of new businesses make it to 15 years or more. This suggests that Knightian uncertainty and associated over-optimism is commonplace among the entrepreneurs that attempt to establish new businesses.

On the other hand, research on venture capital firms imply that some entrepreneurs have a the ability to judge prospects for success in uncertain settings. Venture capitalists attempt to reduce their risks by assessing whether a new venture is likely to survive and to realize very high profits. They attempt to concentrate their investments in the high tail of the distribution of entrepreneurial ventures. They expect (hope?) that the profits from the 25% that survive will be sufficient to offset their losses from the other 75%. Such investors, of course, operate in an environment of Knightian uncertainty. They believe their intuition, together with the data at their disposal, allows them to identify the firms that are most likely to succeed. Published research suggests that many can do so and thus earn high rates of return on their investments (>50%). (See for example a report on the profits of venture capitalists published by the NBER: https://www.nber.org/digest/may01/how-high-are-vc-returns.)

VI. A Few Conclusions

There are a number of behaviors and consequences that suggest that Knightian uncertainty and entrepreneurship are economically important phenomena—although they are largely left out of the core neoclassical models. Uncertainty explains the existence of rainy-day funds within organizations and households, and it also accounts for the unusually high rates of return realized by many relatively innovative companies.

Entrepreneurship would not exist in a world with perfect information about production and profit opportunities—especially in cases where all relevant phenomena were either mechanically causal or probabilistic with known probability density functions. In such cases, routine production and consumption decisions would be the norm—as posited in the core models and developed in Knight's classic book. However, the experience of the past 150 years or so implies that innovation is a major engine of economic growth and profit. Thus, considerable investments are made in research and development by many of the most profitable firms in the world. This implies that innovation is both economically important and an ongoing activity of many—perhaps most—successful firms—especially large firms, but also smaller firms that have to cope with what Schumpeter termed the gale of innovation.

Entrepreneurial decisions are capable of analysis using tools from neoclassical economics—although they are less predictive in cases where Knightian uncertainty is present than in ones characterized by limited information and ignorance. In the latter case, uncertainty can be reduced by research and also by familiarizing oneself with the leading edge of technological and scientific developments. The latter tend to reduce Knightian uncertainty, although it cannot make decisions in those circumstances entirely routine or predictable, because the effects of innovations cannot be fully understood until they occur.

Nonetheless, a well-informed or especially insightful entrepreneur is more likely to succeed than one who simply chases a dream without undertaking useful background research. Thus, Schumpeterian and Kirznerian creativity and insights have clearly played a major role in the emergence of contemporary commercial societies, with their dense networks of exchange and huge and increasing number of products sold. Economic models that neglect the existence of ignorance, uncertainty, and prospects for useful innovations tend to miss much of that which has driven economic development for the past two centuries in the West and in the rest of the world for the past century.

A partial explanation is competitive innovation, as Schumpeter argued, can "force" firms to invest more in R&D and adopt more flexible production systems than they would otherwise have done. And once the "gale" of innovation begins, it tends to intensify and economic development tends to accelerate—albeit at the same time that increases uncertainty for most market participants.

References

Alchian, A. A., & Demsetz, H. (1972). Production, information costs, and economic organization. *The American Economic Review*, 62(5), 777-795.

Bento, P. (2014). Competition as a discovery procedure: Schumpeter meets Hayek in a model of innovation. *American Economic Journal: Macroeconomics*, 6(3), 124-152.

Brouwer, M. T. (2002). Weber, Schumpeter and Knight on entrepreneurship and economic development. *Journal of Evolutionary Economics*, 12, 83-105.

Decker, R., Haltiwanger, J., Jarmin, R., & Miranda, J. (2014). The role of entrepreneurship in US job creation and economic dynamism. *Journal of Economic Perspectives*, 28(3), 3-24.

Kirzner, I. M. (2015). *Competition and Entrepreneurship*. Chicago, IL: University of Chicago Press.

Knight, F. H. (1921). *Risk, Uncertainty and Profit*. Boston MA: Houghton Mifflin.

Schumpeter, J. A. (1939). *Business cycles* (Vol. 1, pp. 161-174). New York: Mcgraw-Hill.
Schumpeter, J. A. (2013). *Capitalism, Socialism and Democracy*. London: Routledge.