Chapter 8: Uncertainty, Innovation, Entrepreneurship, and Progress

I. Introduction: Surprise Events

Knightian uncertainty exists in choice settings in which unanticipated "shocks" may disrupt one's plans. They may do so by subjecting individuals to less attractive or more attractive alterations in their circumstances. In some cases, individuals may be entirely surprised by shocks that they have never imagined. In others, the shocks may have been regarded as possibilities, but ones that cannot be characterized by probability functions or causal chains. In the first case, unanticipated shocks would 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." However, after a surprise happens, 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, because relative prices have been slightly or radically altered, possibly because entirely new products or risks are now confronted. After the fact, the possibility of surprise events is recognized and they may subsequently influence individual plans, as developed in the first part of this chapter.[1]

Examples of shocks characterized by Knightian uncertainty include many natural events such as earthquakes, volcanic eruptions, pandemics, or significant changes in weather. Such events may all be regarded to be possible without being fully characterized by probability functions or causal theories. Other unpredictable surprises are 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.

Although surprises are inherently unpredictable, once the possibilities of unpleasant surprises are recognized, individuals can take such possibilities into account when making plans. Individuals and organizations cannot do so as systematically as when all relevant possibilities and consequences

[1] Of course, surprises may be ignored as possibilities even after they have been experienced because it is too costly to investigate them. If at least some individuals ignore the possibility of future surprise events, the models worked out in previous parts of this book would remain useful models of such individuals. However, once the possibilities of pleasant and unpleasant surprises are recognized, both individual and organizations may alter their behavior to take account of them in various ways that have economic consequences—many of which are explored in this chapter.

can be represented with probability functions and causal chains, but there are many steps that can systematically reduce the downside risks associated with unpleasant surprises, or which can increase the likelihood of pleasant surprises. Although the specific details of surprises cannot be known beforehand (by definition), they may still influence individual plans in ways that are economically relevant.

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

Surprise events may be generated by the unknowable or by the knowable, but ignored risks associated with particular circumstances. For example, geologists use the notion of "100-year floods" when they analyze the flooding and erosion caused by rivers and oceans. Such floods are—geologists or meteorologists believe and normally have estimated—are severe ones that occur roughly every century. A thousand-year flood is even more intense and rare. Persons purchasing land in the 100-year flood plain or those subject to other long-term risks may ignore such rare events. They do so by "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 or twenty years. Alternatively, there may be events that are totally beyond the imagination or knowledge of such persons—a meteor crash—which may alter the value of their investments in a way that is entirely unknown to them rather than simply ignored.

Complexity and ignorance can generate considerable residual uncertainty and tend to have similar effects on the plans made by forward looking individuals. Ignorance implies that the plans adopted fail to take account of all relevant possibilities and so tend to be error prone—in the sense that individuals may later regret their earlier decisions. Complexity implies that some possibilities may be recognized without being fully understood. Both acknowledged ignorance and complexity thus imply that an individual's plans tend to be imperfect.

However, the persons that have experienced surprises in the past may take a variety of steps to mitigate the downside risks associated with such events—including possibilities that they have not explicitly taken into account. One common method of taking unpleasant surprises into account is to accumulate reserves that can be used to mitigate a wide variety of uninsurable downside risks.

Cash and bank accounts can serve this purpose. Liquidity 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 sufficient funds to stay in a hotel or rent an apartment, until the flood recedes, and repairs (if possible) are made. Such reserves are useful whether the problem is a flood, an automobile wreck, an unexpected illness, earthquake, etcetera. In this manner, a "rainy day" fund can ameliorate the downside risks of a wide variety of unpleasant surprises—and it also suggests another reason for saving. Saving is not just about shifting spending power from the present to the future, but also tends to be useful as a method of reducing losses from both unpredictable and uninsurable risks.

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, nor necessarily its source. (A house may well survive a neglected 50-year flood but not a 100-year flood, earthquake, or tornado.)

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 and induce a more careful analysis of the possibility of unpleasant surprises.

Another strategy that can be used when the phenomena generating the surprises is thought to be probabilistic or causal, but the relevant probability distribution or causal chain is simply unknown to individuals or to humankind. In such cases, one may undertake research to learn the relevant underlying probably functions and causal connections, and then use that information to determine optimal reserves (expected utility maximizing or disruption minimizing reserves, etc.) when insurance is not available.

Knightian uncertainty tends to be reduced as knowledge is accumulated, but at least to this point, the accumulation of knowledge has not eliminated uncertainty in Knight's sense. When a "reasonable" investment in research is not sufficient to determine the relevant probability functions or causal chains, the phenomena remain uncertain in Knight's sense even when its frequency can be roughly estimated and subsequent research by others may provide causal or probabilistic explanations for it.

Time is a scarce resource for all individuals and organizations, and thus obtaining such knowledge may be too expensive to undertake or ultimately impossible. (Remaining ignorant of many details thus can be a rational strategy.) And, of course, it may turn out that such phenomena are not amenable to probability or causal explanations. 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, obviously, cannot be known with certain or even probabilistically beforehand. Moreover, the discoveries generated by such efforts may also be sources of uncertainty, as with the Heisenberg uncertainty principle..

Fortunately, uncertainty may also produce pleasant surprises as well as unpleasant ones.

III. A Short Account of the Increase in Economically Relevant Surprises

Neoclassical economics assumes perfect predictability and stability in the models it uses 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 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 phenomena. 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 were coordinated by market prices (Hayek, 1945).

The assumption of stable market relationships was plausible when classical economics 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 most were not very different from the ones made in the previous century or so.

However, there were many obvious breakthroughs in production technologies during the late nineteenth century. Initially, it could be argued that relatively little was known about the new production methods outside the mines and buildings in which new methods of production were used. Consumers are more interested in the nature of the products that they may buy than how they are produced. For example, clothing went through cycles of fashion as usual, but production of the cloth out of which it was made was increasingly automated. Both spinning and weaving were increasingly propelled by wind, water, steam, and electricity rather than human muscles. However, such changes made little difference to consumers except insofar as the cost of clothing fell, freeing their income for other purposes. The latter was a pleasant surprise rather than a threat—except to those whose profession was weaving or support of such weavers. Moreover, changes in production methods often proceeded slowly as rival firms figured out how the occasional innovator managed to produce rival products more quickly or cheaply.

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 steamship was more than a new type of sailboat. The automobile and airplane were new modes of transportation not simply enhancement 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 slightly refined methods of painting, 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.

Thus more people were working in larger firms than before, and products were increasingly produced in other places by people one had never met or heard of.

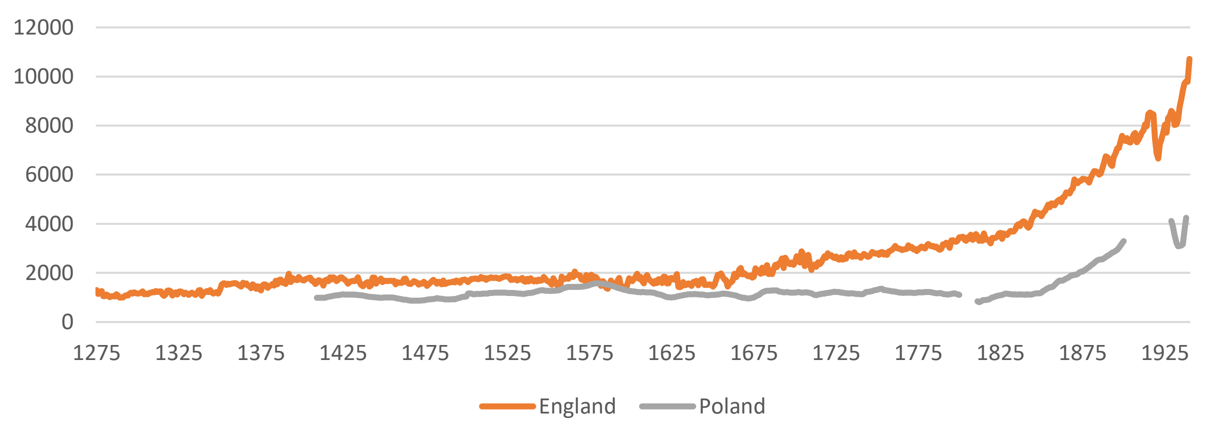
And, although there had been rich people for thousands of years, they were mostly persons that owned or controlled large pieces of land. In the nineteenth century, the persons that created new organizations to produce new goods and services in new ways often became rich. At first, they were looked down on by the wealthy landowner class and chided for being "capitalists" or grubby "industrialists." But gradually, the large landowners either also became capitalists themselves 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.

Figure 8.1 Real Per Capita GNP 1275-1940, England and Poland



(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.

Nonetheless, this was not a source 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, television, satellite maps, and the internet.

IV. Uncertainty, Innovation, and Entrepreneurship

Innovation is possible because of gaps in human knowledge that create possibilities for pleasant surprises as well as unpleasant ones. Not all value-adding possibilities are known at a point in time, and perceiving a new possibility often requires a bit of insight and luck. 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. With respect to product developments, such walks may generate epiphanies about previously unrecognized opportunities for profits. One may not experience the unexpected beauty or turn one's mind loose to perceive previously unrecognized possibilities.

Of course, pleasant surprises are not all stimulated by walks in the country side, new insights and epiphanies may occur by setting aside time for forming a clearer understanding of one's possibilities or by undertaking research and development of an idea that seemed potentially profitable when one first though of it. After experience a strong wind, one may believe that the wind could be harnessed to provide a motive force for sawing boards or making cloth from thread. One can not know this for sure, without investigataing it feasibility. To know, one may have to gamble some resources on experiments to learn whether or not wind can actually be fruitfully harnessed. If one guesses correctly, the result will be a new easier way to produce lumber or cloth and an increase in ones profits. If not, the research may be undertaken without any result of value. However, if one never undertakes the research and development, such pleasant surprises (here, a significant increase in one's net income) would never have been realized.

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 using resources to make an unpleasant surprise less likely to be experienced or to reduce the associated losses below whata they would otherwise have been.

In neither case could one have accurately describe a probability function that characterizes the process through which the phenomena sought or avoided emerge. Nonetheless, one can use statistical types of statements to describe one's thought process. The "probability" of success may be an educated guess, rather than a frequency distribution generated by careful experiments and observation. Probabilities in such cases indicate the extent of one's confidence about whether some positive 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 or avoid—and in both cases, it is quite possible that nothing extraordinary will happen. Potential innovators often fail, and rainy-day funds may prove unnecessary because no unpleasant surprises were xperienced.

One of the innovations of the nineteenth century was the idea 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 a short overview of four theories of entrepreneurship.

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 from 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, someone 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 Economic 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 indirectly by causing particular well-understood products or methods of production to be under used or used inappropriately, or directly as when completely feasible technological innovations exist, but are presently unknown or unrecognized. As a consequence, many profitable new production methods fail to be used and/or many profitable products are not brought to markets.

Research and development activities—when appropriately focused and organized—can reduce ignorance and produce profitable innovations although not with certainty. Of course, part of the puzzle is how to organize and focus those efforts, but initially we'll assume that an 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 is $\Phi = \Phi^0$ 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 $\Phi^e = f(R)(\Phi^0 + \Delta) + (1-f(R))\Phi^0$. 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 more or less the usual way. We first use the implicit function theorem to characterize Acme's inverse demand function, $P=p(Q, \Phi)$, then write down Acme's profit function:

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

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. I'll use the subscript form of notation for partial derivatives to reduce the number of terms that need to be written down.

$$\Pi_Q^e = f(R)[P^\Delta + P_Q^\Delta Q] + (1 - f(R)\big[P + P_Q Q\big] - C_Q = 0 \tag{8.2a}$$

$$\Pi_R^e = F_R P^\Delta Q + (1 - F_R) PQ - C_R = 0 \tag{8.2b}$$

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 the ideal values of the two control variables to be expressed as functions of the parameters of the choice setting. In this case we find that:

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

and

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

The values for prices and expected quality are determined by substituting these ideal values into those function. Pricing is a bit tricky here, because of the uncertain quality, and would most likely be adopted once it is known whether R&D was successful or not. Alternatively, the price of the firm's output might be determined initially 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 book. Thus comparative statics cannot be directly undertaken using the approach used to characterize equations 8.3a and 8.3b without additional matrix-based tools. These are rarely used in contemporary research and so they are neglected in this textbook. There is, however, a substitution method that allows comparative statics to be undertaken, as outlined below.

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

The basic method is to hold one of the two control variables constant and 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 partial derivative with respect to output, Q.

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

(Subscripts 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.

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

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.

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

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 are greater than its effects on marginal cost. This is the relevant range for firms. Given this assumption, the numerator is positive, and the firm's output will increase as R&D expenditures increases because it is increasingly likely that the quality of the product will increase.

To determine the extent of R&D that maximizes profits, we can substitute equation 8.5 (the function characterizing the ideal output level) into the profit function and 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:

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

A simpler notation, with P^{Δ}denoting $p(Q^{*}, \Phi + \Delta)$ and P denoting $p(Q^{*}, \Phi)$ will reduce somewhat the notational complexity of the derivative of expected profits with respect to R&D.

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

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—where output and pricing adjustments are taken into account. The first order condition is somewhat complicated.

$$\Pi^{e}_{R} = [F_{R}P^{\Delta}Q^{*} - F_{R}PQ^{*}] + F(P^{\Delta}_{Q}Q_{R}Q + P^{\Delta}Q_{R}) +$$

$$(1-F)(P_{Q}Q_{R}Q + PQ_{R}) \quad - C_{Q}Q^{*}_{R} - C_{R} = 0 \; at \; R^{*} \tag{8.8}$$

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. With the subscript notation employed for partial derivatives, the first order condition is not too long although it includes the effects of R&D on prices, output, costs, and the probability of innovation. We know from equation 8.4 that $f(R)[P^{\Delta} + P^{\Delta}_{Q}Q] + (1 - f(R)\big[P + P_{Q}Q\big] - C_{Q}$ at Q*, which implies that the second, third, and fourth terms equal zero, because they are just that first order condition multiplied by Q_{R}.[2] This allows equation 8.8 to be simplified to:

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[2] This simplification is an instance of the **envelop theorem**. In simpler terms, suppose that Π = R(X,Y) – C(X,R). Differentiating Π with respect to X yields R_X-C_X = 0 at X*, which the implicit function theorem implies can be used to characterize X* =x*(Y). Thus Π* = R(X*,Y) – C(X*,R). Differentiating Π*with respect to R yields $\Pi^*_R = R_X X_R - C_X X_Y + R_Y - C_Y = 0$ at Y*. Note that this is just $(R_X - C_X)X_Y + R_Y - C_Y = 0$. The first term is always zero at X* so this reduces to $R_Y - C_Y = 0$. This type of cancellation is true of all partially optimized objective functions. The profit maximizing level of Y sets its marginal revenue equal to its marginal cost. In other words, that is what one gets if you ignore the effect of Y on X*. You can do so because those effects cancel out.

In general, the **envelop theorem** says that if you have a partially optimized objective function with just one of the control variables taken into account, the derivative of that function with respect to other control variables can be found by ignoring the variable already optimized, here

$$\Pi_R^e = [F_R P^{\Delta} Q^* - F_R P Q^*] - C_R = 0 \; at \; R^* \tag{8.9}$$

The implicit function theorem allows R* to be written as a function of the choice setting's parameters, which closely resembles equation 8.3b above although in this case it takes account of the effects of R&D on output levels through the Q* function:

$$R^* = g(\Phi, \Delta, w, r) \tag{8.10}$$

Given this function, the ideal output level is:

$$Q^* = s(R^*, \Phi, \Delta, w, r) \tag{8.11}$$

And the associate price is

$$P^* = q(Q^*, \Phi^e) \text{ and } \Phi^e = f(R^*)(\Phi^0 + \Delta) + (1\text{-}f(R)\ \Phi^0 \tag{8.12}$$

The effects of the parameters on the quantity produced can be characterized in much the same way. Conversely, the comparative statics of with respect to R* can be derived by reversing the steps and first characterizing R*, then substitution R* into the profit function and taking derivatives of that partially optimized objective function and relying upon the envelop theorem to simplify the derivatives. Of course, in the other cases, one is not interested in the first order condition, but simply the sign of the derivatives.

Multidimensional R&D—Advantages of Diversification

The above model assumes that a firm has only a single product—as true of most neoclassical models of the firm. However, in reality, most firms produce and sell a variety or products. In some cases, those products consist of variations of a single type of product. As an automobile producer may produce several different forms of fairly similar automobiles—but ones with differences that consumers care about and respond to. R&D in such cases tends to be similarly multi-dimensional, with refinements potentially carried out in several different ways for a variety of products.

Both their multi-product lines and the exploration of many types of refinements tend to reduce the risks associated with the firm's production and profits. By having several product lines, firms reduce risks associated with relatively small shifts in consumer tastes and variation in

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X, and simply taking the partial derivative of the optimized objective function with respect to other control variable(s) of interest, here Y. It was R in the text.

consumer income. By conducting research and development on a variety of refinements, they both gain a better understanding of the risks of failure ins such efforts, and by diversifying reduce the overall probability that all refinements will fail to produce results that add to profits. That process also makes such failures possible by contributing to a better understanding of what "their" customers wan from their products and the sorts of refinements that they are willing to pay for.

The latter allows educated guesses to be made about the kinds of refinements to focus on and those that are very unlikely to be profitable. It thereby creates a domain for their efforts and limits the range of innovations that such firms actively pursue at a moment in time. This is more difficult to do when the goal is major innovation (disruptions), rather than refinements.

Knightian Uncertainty and Entrepreneurship

The Knightian choice setting is difficult—if not impossible—to model, unless entrepreneurs use a though process similar to that above, but use probabilities and conditional probability functions that are just informed guesses (subjective probabilities) rather than actual frequencies. In such cases, entrepreneurs may use educated 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, an entrepreneur's confidence in his or her guesses about the f(X) function and his or her risk aversion.

That confidence can be grounded in an entrepreneur's superior ability or better access to relevant information (as in Schumpeter or Kirzner) or it may be grounded in differences in attitudes toward high-risk settings, what some term "animal spirits" as in Knight's approach to Entrepreneurship. It would also vary with the expected time delay between the R&D and the period in which sales would increase. That is, differences in time discount rates may also matter.

Given assumptions about intuitions or guesses about potential sales, profits, and the probability of success, the previous analytics can be used to characterize firm/entrepreneur decision in cases of Knightian uncertainty as well. 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), this tends to be true of startups. 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 continue for 15 years or more. This suggests that Knightian uncertainty and associated over optimism is commonplace when a new business is established.

Investors in new businesses (venture capitalists) attempt to reduce their risks by investing in several companies that they believe have good prospects of success—while acknowledging the high failure rates of new enterprises. 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, also 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 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 relevant 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 also the existence of unusually high rates of return from relatively innovative companies.

Entrepreneurship would not exist in a world with perfect information and phenomena that were either mechanically causal or probabilistic. In such cases, routine production and consumption decisions would be the norm—as posited in those core models. However, innovation appears to be a major engine of economic growth and considerable investments are made in research and development by many of the most profitable firms, which suggests that innovation is both economically important and an ongoing activity of many firms—especially large firms, but also smaller firms that have to cope with what Schumpeter termed the gale of innovation.

Entrepreneurial decisions, however, 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 familiarizing oneself with the leading edge of technological and scientific developments. Such efforts, arguably, also reduce Knightian uncertainty, although it cannot make decisions in those circumstances entirely routine or predictable. 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, talent, and insights play a role in entrepreneurship, as does Knightian luck. R&D activities may well be greater than modelled in this chapter, because 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" begins, it tends to intensify, and economic development tends to accelerate. To get at these effects a game-theoretic extension of the R&D model developed in this chapter is required, as will be undertaken in Chapter 13.

Economic models that neglect problems associated with ignorance and prospects for useful innovations tend to miss much 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 and a half. It also fails to account for savings decisions rooted in efforts to establish rainy day funds.

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