# Chapter 8: Ignorance, Uncertainty, and Entrepreneurship

## I. Introduction

Chapter 8 is a transition chapter which is appropriate for a chapter that is, in a sense, about transitions. It marks a methodological transition, in that it is the first chapter that strays from the conventional core ideas and models of neoclassical economics. It is the first of many chapters that introduces applied microeconomic topics that are rarely covered in microeconomic textbooks, although they analyze economically important factors. The models are drawn from the published literature and reflect my efforts to distill the core ideas from what by now are very broad literatures.

It is also the first chapter that does not proceed through a series of models of the same phenomena, going from geometric to calculus-based models of the concrete and then abstract form. In most of the previous chapters, a sequence of almost identical models was used to provide a bridge from undergraduate course build on geometry to calculus based ones based on abstract models. By now students should be familiar with all three types of models and the text will generally use abstract models when they are tractable, and models grounded on concrete functional forms where they are either more tractable or help shed light on the results of more abstract treatments. Diagrams are used to illustrate the results generated or to indicate directions that the mathematical models develop.

The written representations of calculus results also shift from the $\frac{dy}{dx}$ form of presenting calculus-based models and results to a form that is more widely used in published work. Subscripts such as $Y_X$ are used denote the partial derivatives, in this case of Y with respect to X—e.g. the same relationship that the $\frac{dy}{dx}$ form is used to communicate. This formulation allows a more compact presentation of results. $Y_{XX}$ in this notation is the second derivative of Y with respect to X.

Because many of the topics reviewed from here on have not been covered a student's past economic courses, the chapters also tend to have more space devoted to explaining why a topic important and how it connects up with the others analyzed in other chapters. The prose often draws on results from the previous chapters. Thus, there are more words and a bit less math in most of the remaining chapters than in the first seven chapters.

This chapter also begins the focus on internally generated transformations of markets, which is the theme of several of the remaining chapters. A common feature of contemporary commercial societies is that new products and new production methods are constantly being introduced. This was less true of markets prior to the nineteenth century, where many, perhaps most products and occupations, would have been as familiar to an urban resident of Athens in 200 BC as to a resident of London in 1800. That would be less true with respect to the product mix available to residents of major Western cities in 1930. Although neoclassical price theory sheds light on how markets operate in the short and medium term, it sheds less light on how they develop in the long run. Rather than constantly producing more of the same products in familiar ways, the product mix itself changes and the production methods used to conceive and bring them to markets change through time.

Many of these transformations are initiated by a handful of innovators who bring new products, new production methods, and new organizations into existence.

The persons that do so are termed "entrepreneurs," and the long-term result of their efforts is that many of the products previously sold disappear as newer and "more useful" products are introduced and catch on in the sense that consumers spend their money on the new products and less on older ones. Recent examples include the transition from paper and pencil, to slide rules, to calculators, to computers, to laptops, to cell phones as methods of doing challenging bits of arithmetic. Shifts in transportation from foot, to horse and buggy, to railroad, to automobiles to jet airplanes is another.

The past century and a half witnessed many such transitions, and this chapter attempts to model common features of the decisions that produced those transformations of both single markets and market systems.

Market-driven transitions of the variety focused on in this chapter are possible only because of ignorance. At time $T^0$ people either did not understand that there was a latent demand for a product with various characteristics, or if they did understand the such demands, they did not know how to produce it. In both cases, ignorance was a barrier that made markets less efficient than they could have been. Potentially realizable gains from trade remained unrealized.

This property of market systems—which Schumpeter termed "creative destruction"—has played a major role in the past two centuries of economic development.

## II. The Acceleration of Economically Relevant Innovation

Perfect predictability and stability are assumed in neoclassical models used to explain market prices. Firms attract and retain their labor forces and ongoing contractual relationships with other input providers. Firms are well aware of other technologies and potential input providers that could be used, but choose those that minimize the cost of producing a product of "standard" quality. 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 understand input prices, the wants of consumers, and the prices consumers are willing to pay to satisfy those wants. Similarly, consumers understand the full array of available products, their "normal" prices, and their uses to advance their personal interests.

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 (Say's Law). Approximately the same products are produced and sold in the same manner every year. The effects of 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. This was, they argued, because decisions throughout market networks are 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 two.

In contrast, there were many obvious breakthroughs in production technologies during the nineteenth century. 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.

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 enhancements of the old ways—methods that had been based on animal muscle power for millennia. Telegraphs and telephones were not simply fast-arriving letters. Photographs, indoor plumbing, and washing machines were not simply slightly refined methods of painting, delivering water, disposing of wastes, or cleaning one's attire. Patterns of life were changing.

Taking advantage of the new production methods often required far larger organizations, with more specialized personnel and machine than their ancient 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. More extensive and dense market networks gradually emerged as profitable opportunities for specialization, firm expansion, and extended trading networks came to be understood and taken advantage of.

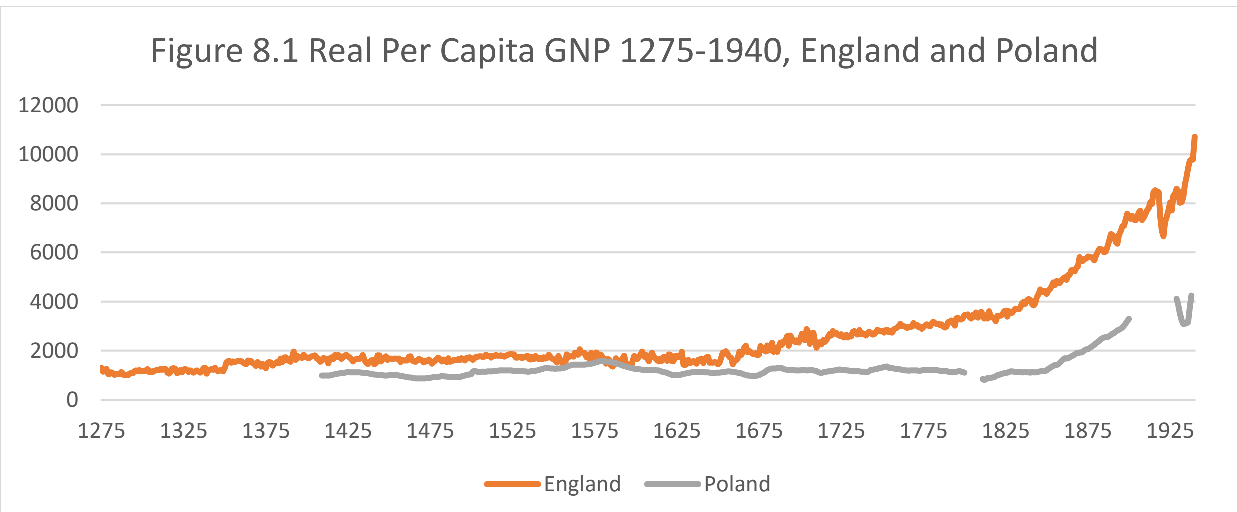
Although there had been rich people for thousands of years, prior to the nineteenth century, the rich were mostly persons that owned or controlled large pieces of land. In the nineteenth century, an increasing number of persons became wealthy by producing new goods and services in a manner that was unconnected to agriculture. Such persons were often chided for being "capitalists" or grubby "industrialists." But gradually, the large landowners either also became capitalists themselves or 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, market 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.

Some types of certainty diminished while others increased. Yet, the overall effect was a more prosperous society.  Average income and longevity increased.

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 in 1400, they were approximately the same.

Although this period of accelerating commerce was well underway by the time that neoclassical economics emerged, theories of innovation have still not found their way into neoclassical models or textbooks. This was partly because it was not easy to model.

## III. Ignorance, Uncertainty, 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 taken early in the Spring with the hope of seeing early flowers or returning birds. A similar walk by entrepreneurs may generate epiphanies about previously unrecognized opportunities for profits. Yet, putting those ideas into practice is rarely as easy as a walk in the park. When successful, an entrepreneur (or his team) may perceive, discover, and implement methods that allow previously unrecognized profitable opportunities to be realized. A good deal of work by many talented persons may be required to work out a profitable way to produce a new product.

For example, after experiencing a strong wind, a person with an entrepreneurial bent may believe that the wind could be harnessed to provide a motive force for sawing boards or making cloth from thread. The first persons with such ideas could not know this for sure. They would have to investigate its feasibility. To do so, one has to gamble some resources on experimental structures to determine whether or not wind can actually be fruitfully harnessed. If one works out such methods, the result will be a new easier way to produce lumber or cloth and an increase in one's profits.

If not, the research may be undertaken without any result of value. However, if one never undertakes the research and development, because the outcome is subject to a good deal of Knightian uncertainty, such profits and their associated gains from trade would never have been realized.

In effect, both these activities are the opposite of rainy-day funds. They use resources to make a pleasant surprise more likely to be experienced—rather than using resources to make an unpleasant surprise less burdensome than they would otherwise have been.

In neither case could one have accurately described a probability function that characterized the process through which the phenomena sought or avoided emerge. Nonetheless, one can use statistical ideas to describe one's thought process. The probability of success must be weighed against the probability of failure, and the expected benefits against their costs in much the same way that would be necessary if one knew the relevant probabilities.

The logic of expected values and maximum likelihood approaches remains useful even if the "probability" of success is 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.

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 century, 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 "Uncertainty" 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.)

Frank Knight regarded entrepreneurial profits to be results of "gambles" where neither the odds nor the payoffs are known beforehand—which is to say circumstances of Knightian uncertainty. Entrepreneurs who profit from innovation or other forms of speculation are simply lucky. 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 specific 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 beforehand, 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, average 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 "uncertainty" takers, not in the sense of taking well-understood gambles (risk), 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 (uncertainty).

## A Model of Knightian Entrepreneurship

> Uncertainty must be taken in a sense radically distinct from the familiar notion of Risk.... A measurable uncertainty, or 'risk' proper, is so far different from an unmeasurable one that it is not in effect an uncertainty at all. [Knight, F. H. (1921): p. 19–20.]

Suppose that a potential entrepreneur is considering a discrete investment I that will he or she expects generate a profit of Π, if successful and 0 otherwise. He or she believes that the probability of success is F. In circumstances of uncertainty, both Π and F are subjective assessments only weakly linked to data or experience. He or she invests if the subjective expected rate of return is greater than his or her (risk adjusted) rate of return r, which is to say, if $\frac{F\Pi}{I} > r$. If there is a group of potential entrepreneurs, the ones that "take the plunge" are those whose estimated profits are sufficient above the required investment to exceed their opportunity cost rate of return.

Suppose that the opportunity cost rate of return is the same for all potential entrepreneurs and that their estimates of Π are all the same, but they disagree about the probability of success. In this case only the most optimistic persons (the ones with highest subjective probabilities of success) make the investment. If the true realizable profit level it below that required to profit from the investment even when F=1, all who invest will lose their investments or earn a below average return on their investments. (This is an instance of the so-called "winner's curse" in auctions.)

But suppose that the true profit is sufficient to generate relatively high profits if an entrepreneur's implementation of his or her investment is well-conceived and executed. In that case, the fraction of entrepreneurs who make the investment and undertake the well-conceived plan tend to profit (possibly at extraordinary levels) and those who do not fail. In this case, there will be a mixture of winners and losers, with ratios based on how well they allocate their investments (which would largely be based on how accurate and complete their subjective probabilities are). Some investors realize lower than normal return and others higher than normal rates of return, as in the Knightian model.

## 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]).

Joseph Schumpeter was doing his research during the same period as Frank Knight, but on the other side of the Atlantic and in a different language. Rather than focusing on risks and uncertainties associated with commercial societies as they had emerged in the early 20th century, Schumpeter was more interested in the innovators and innovations themselves and how they affected market equilibria. He was among 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 dominate textbooks and journals—and still do outside the relatively small group of economists that focus on innovation. (See Tzeng, 2008, for a survey of the late 20th century literature on innovation.)

Schumpeter's first books in this area were written in German and attracted little attention outside the German speaking parts 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 University shortly after the book was published. A shorter simplified version of his theory was included in his most widely read book *Capitalism Socialism and Democracy* (1942).

According to his theory, in the absence of innovation, markets reach an equilibrium that resemble stationary circular-flow systems—analogous to a Walrasian general equilibrium with a steady state supply of capital and labor. In this, his point of departure is similar to that of Knight's, although it has Walrasian rather than Marshallian foundations.

However, their focus differs. Schumpeter is interested in the effects of innovation on economic development, rather than the effects of uncertainty upon a stable equilibrium. By the early twentieth century it had become obvious that major innovations disrupt the preexisting equilibria—sometimes radically so. And, major innovations generate additional sources of mutual gains to trade, 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. It is clear that without imperfect information, such opportunities would not exist. Similarly, it is clear that if everyone had the same information and expectations, unnoticed profitable 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 focuses much of his attention on major innovations—disruptive innovations—exactly the same type of analysis applies with respect to profitable refinements of preexisting devices, services and methods of production. Such less disruptive innovations also often require unusual insights (or luck) as well as persistence and organization.

## A Model of Schumpeterian Entrepreneurship

In his published work on innovation, Schumpeter emphasizes that innovation tends to expand markets—even if *d* products disappear. Previously stable k-good worlds are transformed into (temporarily) stable $(k + n - d)$-good general equilibrium models after the $n > d$ new products have been brought to market and been fully accounted for by other firms and consumers. The basic choice problem confronting individual entrepreneurs is similar to that modelled above for Knightian entrepreneurs, but in Schumpeter's case, the entrepreneurs are persons able to penetrate the previous perceived boundary of profitable opportunities created by ignorance and understand the true likelihood of success (F) and have a clear estimate of the potential profit (Π) for products not currently being produced (or, in some cases, imagined). They undertake the entrepreneurial investment if $\frac{F\Pi}{I} > r$.

The genius required to do so limits the number of successful entrepreneurs when significant breakthroughs are generated. There are a few winners, but few losers except those whose products lose out to the new ones. Secondary products require less genius than the primary innovation and more products are introduced by a second wave of innovation entrepreneurs whose products complement those of the primary innovators. This continues until the breakthrough innovation and its ramifications are fully exploited and a new equilibrium established—one soon to be disturbed by the next breakthrough entrepreneur(s).

### Israel Kirzner: Entrepreneurs as Equilibrators

> 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. Full-time entrepreneurs 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 are perceived more clearly or more rapidly than by others. Kirzner also suggests that we all are part-time entrepreneurs insofar as we all adjust our plans to take account of new circumstances and their associated opportunities for gains to trade.

## A Model of Kirznerian Entrepreneurs

Kirzner's theory of full-time entrepreneurs—e.g., of persons 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 from those stressed by Schumpeter. Rather than 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.

Kirzner's characterization of the entrepreneur is that of an arbitrager, with the notion of arbitrage generalized to include the construction of new products by putting together "pieces" that all or mostly already can be found in markets. It thus includes innovation as a source of entrepreneurial profits (Π) that similar to that imagined by Schumpeter although it is framed differently. As in Schumpeter, Kirzner's full-time entrepreneurs are rare because of the required high degree of "alertness" to market opportunities required. Neither Kirzner nor Schumpeter acknowledge the importance of Knightian uncertainty, and therefore neither of their entrepreneurs make mistakes.

Kirzner's notion of entrepreneurs as equilibrators can also be interpreted in informational terms. By recognizing instances of previously unnoticed unrealized gains to trade, they indirectly bring the existing market closer to the imagined full-information equilibria of the core neoclassical models. In that sense, they are equilibrating forces rather than disruptive ones—although disruptions must surely occur for major instances of formerly unobserved mutual gains to trade.

## 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 many profitable 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 their employee-team members and sufficient profits to maintain the organization's 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, Steve Jobs, Bill Gates, Jeff Bezos, and Elon Musk to name just a few founders of large innovative and very profitable organizations. Many others exist throughout the world, and a significant subset of them were both founders of large commercial companies that were Knightian uncertainty-bearers and Schumpeterian disruptors.

## IV. Routine Innovation: Improving Quality: Innovation without Significant Disruption

All the above suggests that there is a continuum of innovation that is incentivized by markets. 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 profit from an unusually clear understanding of possibilities and probabilities, ones neglected by others. Their more accurate perceptions of opportunities allows them to at least temporarily profit from their insights. The extent of the insight required varies with the "size" of the innovation required to generate supra-market rates of return. Some are major, as in Schumpeter's model of entrepreneurs as disruptors. Others are relatively minor, although not trivial, as with profitable refinements of existing products, in which case there is relatively little uncertainty that needs bearing.

The latter, refinements of existing products, are commonplace in contemporary commercial societies. Disruptions, although not uncommon in recent decades, are naturally less common than year-to-year refinements—which over time may also transform the product and occupational mix of a commercial society.

### Modest Intentional Innovation

Research and development activities—when appropriately focused and organized—can reduce ignorance and produce profitable innovations with a high degree of predictability, without much uncertainty. Part of the puzzle is how to organize and focus R&D efforts, just as part of the puzzle of producing things for sale requires organizing a supply chain, factory floor, and teams to engage in manufacturing and assembly. Nonetheless, we'll abstract from the nitty gritty of how to conduct R&D, which will vary by market, and 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, $\Phi$, $Q^D = q(P, \Phi)$. We'll assume that Acme is a price maker and use its inverse demand function to construct a revenue function. The price at which Q units of the product varies with its quality. It is $P = q(Q, \Phi^0)$ if R&D is unsuccessful, quality is unchanged, and it is $P^\Delta = q(Q, \Phi^0 + \Delta)$ if R&D is successful.

The probability of success increases with R&D expenditures, R, $F = f(R)$. This allows expected quality to be characterized as $\Phi^e = f(R)(\Phi^0 + \Delta) + (1 - f(R))\,\Phi^0$. The cost of producing the product is 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, Φ), then write down Acme's profit function:

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

Or equivalently, written out in more detail, as:

$$\Pi^e = f(R)p(Q, \Phi^0 + \Delta)Q + \big(1 - f(R)\big)p(Q, \Phi^0)Q \; - c(Q, R, w, r) \qquad (8.1b)$$

(Notice that for the purpose of this model, other variables that are normally included in a demand function are being abstracted from—assumed constant for the period of analysis.)

Assume that the expected profit function is strictly concave. In that case, the ideal combination of investment in R&D and output levels is characterized by two first order conditions. The first is a partial derivative with respect to output, Q, and the second is a partial 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. $\Pi_Q$ is the partial derivative of profit with respect to output and $\Pi_R$ is the partial derivative of profit with respect to R&D expenditures.

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

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

Note that as elsewhere, derivatives with respect to a variable (normally named with a capital letter) that is a function of some other (normally named with lower case letter) is denoted as the capital letter with a subscripted variable as with $F = f(R)$ *and* $F_R = \frac{dF}{dR}$.

Both partial derivatives are 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:

$$Q^* = s(\,\Phi^0, \Delta, w, r) \qquad (8.3a)$$

and

$$R^* = e(\ \Phi^0, \Delta, w, r) \qquad (8.3b)$$

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 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 only occasionally used in contemporary research and so they are neglected in this textbook. There is, however, a variation of the substitution method that allows comparative statics to be undertaken, as outlined below.

## Using the Envelop Theorem to Characterize 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.

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

The implicit function theorem allows this relationship to be used to characterize Q* as a function of parameters of Acme's choice setting. The profit-maximizing output requires the following first order condition to be satisfied:

$$\Pi_Q^e = \ F[P^{\Delta} + P_Q^{\Delta}Q] + (1-F)\left[P + P_Q Q\right] - C_Q = 0 \qquad (8.5)$$

This is similar to equation 8.2a above, but does not take account of the possibility of altering R, the other control variable.

$$Q^* = s(\ R, \Phi^0, \Delta, w, r) \qquad (8.6)$$

This differs from equation 8.3a because this is a partial optimization, rather than a complete one. It characterizes the output that on average will maximize profits for a given level of the other parameters of the choice setting, including expenditures on research and development. In this respect it is analogous to the profit maximizing choice of a price-making firm developed in Chapter 3, which neglected R&D expenditures. It does not characterize the ideal level of R&D, but treats it as an exogenous parameter of the firm's choice of output.

Substituting Q* into the original profit function characterizes the "envelope" of the Acme's maximal profit levels for given values of $R, \Phi^0, \Delta, w, and\ r$.

$$\Pi^e = f(R)P^{\Delta}Q^* + (1 - f(R))PQ^* - C \tag{8.7}$$

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 a firm's profit through effects on output, price, and production cost. That method can also be used to determine the effect of R&D expenditures on Acme's profits.

In this case, we'll also apply the envelope theorem which implies that we can neglect the derivatives of Q* with respect to R for reasons explained in a footnote below. [1] This produces a relatively simple expression for the effect of R&D expenditures on the Acme's profits:

$$Q_R^* = \frac{H_R}{-H_Q} = \frac{F_R[P^{\Delta} + P_Q^{\Delta}Q] - F_R[P + P_Q Q] - [C_R]}{-\Pi_{QQ}} > 0 \tag{8.8}$$

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[1] The relatively simple form of the numerator of equation 8.8 is a consequence of the **envelope theorem**. In general, the **envelope 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 ignore derivatives with respect to the variable already optimized.

For example, suppose that In the illustration below the optimization takes place in the X domain, and simply taking the $\Pi = r(X, Y) - c(X, Z)$. One may initially focus on control variable X. Differentiating $\Pi$ with respect to $X$yields: $R_X - C_X = 0$ at X*. The implicit function theorem implies that X* can be characterized as $X^* = x(Y, Z)$. Maximal profit (at least as far as X is concerned can be written as: $\Pi^* = r(X^*, Y) - c(X^*, Z)$. Suppose now that we are interested in how variable Z affects maximal profits. Calculus implies that this should be written as: $\Pi_Z^* = R_X X_Z^* - C_X X_Z^* - C_Z$ or $\Pi_Z^* = (R_X - C_X)X_Z^* - C_Z$. At X*, we know that the term inside parentheses, $(R_X - C_X)$, is always zero. It is how we characterized $X^*$, thus the first term has the value zero, leaving only the last term: $\Pi_Z^* = -C_Z$ . Partial derivative with respect to the already optimized variable(s) disappear because it turns out that they have the value zero along the the "envelop" of the partially optimized objective function, here profits.

The term in the denominator is positive, as usual, if the expected profit function is strictly concave. The numerator is more complex. It is essentially the effect of R&D on the firms expected marginal revenues (the first two bracketed terms) and marginal production costs (the last).

The effect of R&D on profits depends in part on how much R&D is being undertaken. If R&D occurs in its profitable range at the margin, the numerator is positive because its effects on marginal revenue are greater than its effects on marginal cost. This is the relevant range for innovative 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.

The ideal level of R&D will set its marginal revenue equal to its marginal cost. Going beyond that level would reverse the sign of equation 8.8, because in that range its effects on marginal revenues would be less than its effect on marginal production costs.

Note that it is also possible that the marginal cost of R&D is greater than its marginal revenue of its entire positive range, in which case the firm does not innovate, beyond incidental observations by managers that happen to increase product quality, but which costs a firm essentially nothing. It invests nothing in R&D and its products do not change very much if at all through time. These are the firms in the core neoclassical models, and remain quite common in market networks.

### Multi-dimensional R&D—Advantages of Diversification

The above model assumes that a firm produces only a single product—as true of most neoclassical models of the firm. However, in reality, most firms produce and sell a variety of products, as taken up in Chapter 11. In some cases, those products consist of variations of a single type of product. An automobile producer may produce several different forms of fairly similar automobiles using a single assembly line—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 several of its 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 variations in consumer income. Having several product lines also somewhat reduces losses associated with the innovations of rival firms (firms selling similar products).

Note that the effect R&D diversification does not depend on complementarities among R&D methods, although it may benefit from those, whenever they exist. Suppose that success and failure are clear and binary, as with a coin toss. Suppose also that there is a 50:50 probability of success from each line of research. The probability of a FF result (both failures) is ¼, whereas the probability of a failure on a single coin toss is ½. So the odds of at least one success increase from diversification (to ¾ from ½).

By conducting research and development on a variety of refinements, a firm's research and development team also gain a better understanding of the risks of failure in such efforts and reduce the probability that all R&D efforts fail to produce results that add to profits.

That process includes efforts to identify promising refinements possible by contributing to a better understanding of what "their" customers want 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 bounds the domain for R&D 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 of familiar products.

## V. Evidence of the Consequences of Knightian Uncertainty

The Knightian choice setting is difficult—if not impossible—to model, unless entrepreneurs use a thought process similar to that above, albeit with probabilities and conditional probability functions that are informed guesses (subjective probabilities) rather than actual frequencies. Given this characterization of the choices of entrepreneurs, innovation can be modelled, although predictions are less susceptible to empirical tests, because subjective probabilities are inherently unobservable, although they may be deduced from behavior.

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 decisions in cases of Knightian uncertainty as well. Because odds of success 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. Knightian entrepreneurs tend to be among the persons with them most optimistic assessments of their probability of success (a relatively high F and Π). They are in this sense over-confident risk takers.

The experience of formal startups is, perhaps unfortunately, more in accord with Knight's model than Kirzner's or Schumpeter's.

According to the U.S. Bureau of Labor Statistics (BLS), the failure rate of startups is relatively high—higher than one would anticipate from Kirznerian or Schumpeterian 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 continue for 15 years or more. This suggests that Knightian uncertainty and associated overoptimism are commonplace among the individuals founding new businesses.

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 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 that 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 and individuals.

Entrepreneurship would not exist in a world with perfect information if all phenomena were either mechanically or probabilistic causal. In such cases, routine production and consumption decisions would be the norm—as posited in the core neoclassical models. However, the evidence suggests that ignorance is economically important, rather than a variable that can simply be ignored.

It is ignorance that creates Knightian uncertainty, the possibility of pleasant and unpleasant surprises, and the possibility for innovation. Innovation is economically important. It is an ongoing activity of most large firms and it is clearly evident in the ever-changing mix of products produced and sold within contemporary commercial societies.

If we regard innovation to be a product of persons termed "entrepreneurs," then models that include the behavior of such persons are necessary if we are to understand how an economy evolves through time. Although the innovations themselves are unpredictable products of imaginative persons and teams, it may nonetheless be possible to include their effects in a general way into our models of markets.

This chapter has sketched out how such models can (and have) been developed in the second half of the twentieth century. Such models are relatively easy to develop if one shifts from settings of risk to uncertainty and assume that entrepreneurs engage in expected profit maximization with subjective probabilities (educated guesses) rather than accurate probability distributions.

The neoclassical models of Part I, in turn, provide insights about how innovations affect market outcomes. They do so by expanding the domain of products, in a manner that can be modelled one market at a time using the neoclassical core as a point of departure.

Reductions in market-relevant ignorance evidently require Schumpeterian and Kirznerian creativity, talent, and insights combined with Knightian luck. And once the "gale" of R&D competition begins, it tends to intensify, and economic development tends to accelerate. To get at these effects game-theoretic extensions of the R&D model developed in this chapter are undertaken in Chapter 13.

Economic models that neglect problems associated with ignorance and prospects for useful innovations cannot account for the economic developments for the past two centuries in the West and in the rest of the world for the past century and a half. Such models cannot account for changes in the product mix sold, the technologies that produce them, and the lifestyle changes associated with greater specialization and employment by large firms. The dynamic aspects of markets are readily explained by extended neoclassical models in which innovation and entrepreneurship are taken into account.

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