



## The Oxford Handbook of Innovation

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<https://doi.org/10.1093/oxfordhb/9780199286805.001.0001>

Published: 2006

Online ISBN: 9780191577314

Print ISBN: 9780199286805

### CHAPTER

## 9 Finance and Innovation

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<https://doi.org/10.1093/oxfordhb/9780199286805.003.0009> Pages 240–265

Published: 02 September 2009

### Abstract

Innovation is an expensive process; significant resources must be expended to initiate, direct, and sustain it. It is a process that takes time which means that the resources that support it must be committed until the process is complete. According to this article, contemporary economists of innovation have largely neglected the relationship between finance and innovation. This article notes that empirical research has not kept pace with theoretical developments and the evidence that does exist, even on basic propositions, is often ambiguous. Furthermore, this article points to serious limitations associated with the dominant analytical approaches employed in micro- and macroeconomic research on finance for analyzing the dynamics of economic change. In closing, it draws attention to some crucial questions that need to be addressed in new research on finance and innovation.

**Keywords:** [innovation](#), [contemporary economists](#), [finance](#), [empirical research](#), [economic change](#)

**Subject:** [Innovation](#), [Business and Management](#)

**Series:** [Oxford Handbooks](#)

### 9.1 Introduction<sup>1</sup>

INNOVATION is an expensive process; significant resources must be expended to initiate, direct and sustain it. It is a process that takes time which means that the resources that support it must be committed until the process is complete. Finally, its outcomes are uncertain so the returns to innovative investments are not assured. The importance of resource allocation to innovation, as well as the complexity of its relationship to that process, makes its systematic analysis crucial to a comprehensive economic theory of innovation.

It is not surprising, therefore, that Joseph Schumpeter, widely regarded as the pioneer in the economic analysis of innovation, made the study of resource allocation, especially the allocation of financial resources, central to his study of innovation. In contrast, as I show in Section 9.2, contemporary economists of innovation have largely neglected the relationship between finance and innovation. Though there are a

few exceptions to this rule, they are too recent and too few to suggest that we are on the brink of any systematic change in this regard.

However, some financial economists working in the fields of enterprise finance<sup>2</sup> and finance and growth have begun to explore concerns that are closely related to those that animated Schumpeter's research. In Section 9.3 I discuss research in these fields that is relevant to the study of finance and innovation. I note that ↪ empirical research has not kept pace with theoretical developments and the evidence that does exist, even on basic propositions, is often ambiguous. Furthermore, in Section 9.4, I point to serious limitations associated with the dominant analytical approaches employed in micro- and macroeconomic research on finance for analyzing the dynamics of economic change.

Intellectual exchange between evolutionary economist and financial economists seems a better route to an improved understanding of the relationship between finance and innovation. However, methodological differences, especially with respect to the importance of history in economic analysis, are major obstacles to integration between the fields. Therefore, it may be more fruitful for economists of innovation to collaborate with economic and business historians who research the origins and evolution of financial systems. In closing, I draw attention to some crucial questions that need to be addressed in new research on finance and innovation.

## 9.2 The Role of Finance in the Economics of Innovation

Schumpeter's analysis of the relationship between innovation and resource allocation, especially the allocation of financial resources, was central to his study of the economics of innovation. Many of the details of Schumpeter's economics of innovation were controversial and/or incomplete and contemporary research on the subject has made considerable progress in refining, and expanding on, his analysis. In particular, questions about the appropriate characterization of the innovation process have received considerable scrutiny. However, with a few notable exceptions, the implications of characteristics of innovative activity for resource allocation, especially the allocation of financial resources, have been largely overlooked.

### 9.2.1 The Pioneering Work of Schumpeter

The role of innovation as the primary stimulus to the process of economic development was the central preoccupation in Joseph Schumpeter's work as an economist. Schumpeter focused on two different, but related, units of analysis in conceptualizing the links between innovation and resource allocation. On the one hand, he was concerned with the implications of the microeconomic characteristics of innovative ↪ activity, notably features of entrepreneurial behavior, for resource allocation. In addition, at a more aggregate level of economic analysis, he studied the interaction between structural economic change and resource allocation. In both his micro- and macroeconomic analyses, he paid particular attention to the role of finance in facilitating economic change though, especially in his microeconomic analysis, his understanding of that role shifted over time.

### 9.2.1.1 The Microeconomics of Innovation

In Schumpeter's early writings on the microeconomics of innovation, especially the *The Theory of Economic Development (TED)* and *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process (BC)*, the process of credit creation featured prominently. Later in his life, however, especially in *Capitalism, Socialism and Democracy (CSD)*, Schumpeter downplayed the role of credit creation in facilitating innovation and economic development. Instead, he emphasized the self-financing of innovative investment by dominant enterprises. The shift in Schumpeter's thinking about the relationship between finance and economic change reflected the well-known transformation in his characterization of innovation from a process driven by new, entrepreneurial ventures to one dominated by large, persistent enterprises.

*The Entrepreneur, the Financier, and Innovation.* Beginning with an analysis of the allocation of economic resources in the absence of innovation, *The Theory of Economic Development* is Schumpeter's initial treatise on the economics of innovation. Schumpeter's central claim was that the competitive capitalist economy would settle into a routine that might be in motion but would tend towards a stationary or equilibrium state. Resources would flow around the economy, along routinized paths, in what Schumpeter described as the "circular flow of economic life." They would be fully utilized in that perpetual motion and as such could not accumulate into stocks (Schumpeter 1996: 45).

Schumpeter then posed the question of how innovation could occur under these conditions. He defined innovation as the commercial or industrial application of something new, such as a new product or process, a new type of organization, a new source of supply or product market (Schumpeter 1996: 66). He emphasized three characteristics of the innovation process that had crucial implications for resource allocation.

First, innovation depended on the investment of resources: "major innovations and also many minor ones entail construction of New Plant (and equipment)—or the rebuilding of old plant—requiring non-negligible time and outlay" (Schumpeter 1939: 68). Second, innovation, as a general rule, was embodied in new firms that are founded to undertake the new combination (Schumpeter 1964: 69; see also Schumpeter 1996: 66).

p. 243 Finally, innovation was usually driven by entrepreneurs who were "new" men, that is, who were not already prominent in business circles (Schumpeter 1996: 78; 1964: 70).

Through the process of innovation, the economy's existing productive resources were to be combined in new ways but how were new men, operating in new firms, to get the control over the resources that they needed in order to innovate (Schumpeter 1996: 68)? Since existing resources were already fully utilized in the circular flow, somehow they had to be detached from their current uses and made available to entrepreneurs so that they could combine them in new ways. What was the mechanism through which resources would be reallocated from existing to new uses in the economy?

The solution that Schumpeter provided to the puzzle put the financial system at center stage. Specifically, he argued that innovation was financed through the creation of credit. The purchasing power required by entrepreneurs to detach resources from the circular flow to undertake new combinations was generated *ex nihilo*. Credit creation did not need to be backed by an existing stock of money or goods (Schumpeter 1996: 106).

Schumpeter believed that credit could be created in a variety of ways but he gave prominence to the role of the commercial bank in generating new purchasing power and making it available to entrepreneurs. In entrusting an entrepreneur with the productive resources of society, "[the banker] makes possible the carrying out of new combinations, authorises people, in the name of society as it were, to form them. He is the ephor of the exchange economy" (Schumpeter 1996: 74).

*The Large-Scale Enterprise, Innovation, and the Role of Finance*. Over the course of his scholarly life, Schumpeter dramatically altered his characterization of innovation from a process dominated by new men and new firms to one driven by the activities of large-scale industrial enterprises. During the period of almost forty years between the writing of *TED* and *CSD*, Schumpeter moved to the United States. He was struck by the major changes underway in the US economy in the first decades of the twentieth century and he believed that they represented a shift from nineteenth-century “competitive capitalism” to twentieth-century “trustified capitalism.”

Whereas previously he had argued that the life and purpose of new firms faded over time, in *CSD* he claimed that the “perfectly bureaucratized giant industrial unit” had succeeded in rationalizing and routinizing the process of innovation to such an extent that the large-scale enterprise had become “the most powerful engine” of economic progress (Schumpeter 1942: 106). As a result, technological progress had increasingly become the business not of individual entrepreneurs but of “teams of trained specialists who turn out what is required and make it work in predictable ways” (Schumpeter 1942: 132; see also Schumpeter 1949: 71).

p. 244 Schumpeter's revised characterization of the innovation process led to important changes in his analysis of resource allocation in a dynamic economy and, in particular, in his analysis of finance. Specifically, it led him to downplay the role of external finance and the banking system in favor of an emphasis on internal finance for facilitating innovative investment. Indeed, for a scholar who once described the process of credit creation as “the monetary complement of innovation” (Schumpeter 1964: 85), the absence of any reference in *CSD* to the process of credit creation, or the specific functions of banks, represents a dramatic change in perspective.

### 9.2.1.2 Finance, Innovation, and Structural Economic Change

Although *TED* is dominated by microeconomic analysis, towards the end of the book Schumpeter sketched the outlines of a macroeconomic analysis of innovation and economic development which he articulated in greater detail in *Business Cycles*. His main concern was with the question of why economic development “does not proceed evenly as a tree grows, but as it were jerkily,” of why there was a business cycle, “the wave-like movement of alternating periods of prosperity and depression,” which he claimed had characterized the economic system throughout the capitalist period (Schumpeter 1996: 223).

Schumpeter's analysis of the business cycle built on the microeconomic analysis of innovation that he had laid out in *TED*, notably in assuming that innovation was embodied in new firms established by new men. It went beyond it, however, in suggesting that the process of venture creation had important characteristics that could only be identified at the aggregate level. Specifically, he claimed that innovative activity was unevenly distributed over time and across industries.

As a result, economic development was an uneven and jerky process (Schumpeter 1964: 76). The effect of booms in entrepreneurial activity was to fundamentally alter the economic system that existed beforehand, disturbing its equilibrium and starting “an apparently irregular movement in the economic system, which we conceive as a struggle towards a new equilibrium position” (Schumpeter 1996: 235). Therefore, he rejected the notion of economic development as a mere quantitative change in the level of aggregate economic activity and argued that it was a process of qualitative change that could only be understood with reference to the structural composition and evolution of the economy.

Having characterized the process of economic development in this way, the challenge for Schumpeter was to explain how such qualitative economic change might occur. Once again, the financial system or, more precisely, the banking system and the credit expansion and contraction that it facilitated, featured as the crucial mechanism that facilitated the reallocation of resources necessary to induce dramatic changes in the structure of economic activity. For Schumpeter, therefore, the evolution of a country's financial system was

of crucial importance for facilitating the waves of innovation that he regarded as the motive force behind its economic development.

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## 9.2.2 The Neglect of Finance in the Contemporary Economics of Innovation

Given Schumpeter's expansive vision of the economics of innovation, it is hardly a surprise that the details of his arguments have been subject to significant critical scrutiny. Most of the attention has focused on his characterization of the innovation process. For example, his assertion of a general historical transformation from an innovation process dominated by new ventures (often described as Type 1 innovation) to one driven by large industrial firms (Type 2) has been rejected. Contemporary scholars have emphasized that both of these patterns of innovation coexist in the economy with some industries characterized by Type 1 and others by Type 2 innovation (Winter 1984: 295).

However, hardly any attention has been devoted to the relationship between innovation and resource allocation even though Schumpeter's analysis of it is as controversial and incomplete as his characterization of innovation. Nevertheless, questions about resource allocation are latent in much of the work that has been done on characteristics of the innovation at the level of the enterprise, the industry and the economy. Like Schumpeter, economists of innovation must develop an explicit analysis of the implications of these characteristics for the allocation of resources and, in particular, financial resources. Otherwise, we might well ask whether contemporary research on innovation as yet amounts to an economics of innovation at least if we define economics, as most people do, as centrally concerned with resource allocation.

### 9.2.2.1 Finance, Innovation, and the Enterprise

One way of reading the implications of Schumpeter's intellectual evolution from *TED* to *CSD* is as a call for a theory of the innovative enterprise. Though Schumpeter was confident that such an important research agenda would not be ignored, the subject attracted almost no attention for more than three decades after his demise. One major exception was a book entitled *The Theory of the Growth of the Firm* published in 1959 by Edith Penrose. Penrose's main argument was that the basic foundation for the growth of firms was a dynamic process of organizational learning that occurred within enterprises.<sup>3</sup> In recent decades, there has been a veritable explosion of interest in conceptualizing innovation as it occurs at the level of the firm. Whether derived directly from Penrose or not, the notion that firm-level innovation is based on a process of organizational learning is an idea that is common, even pervasive, in the literature on the innovative enterprise (for a similar conclusion, see Nelson 1991; Teece, Pisano, and Shuen 1997; see also Lazonick, Ch. 2, and Lam, Ch. 5, this volume).

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Most of the research on the subject of organizational learning in firms makes some reference to the process through which resources are allocated to allow them to initiate, direct and sustain organizational learning. However, it is rare to find systematic discussions of the implications of organizational learning for the allocation of financial resources to investments and returns. One basic question that needs to be addressed is whether, and to what extent, the process of organizational learning affects the scale of investment that must be made by an innovative firm. Resources have to be invested in the learning process itself, as well as the implementation of the results of such learning within the organization. In addition, financial resources are required to develop or acquire the necessary complementary assets (Teece 1986) to commercialize innovations based on this organizational learning. However, very little research has been conducted on the implications of the characteristics of organizational learning for the resource requirements of different types of enterprises.

If the organizational character of the innovation process has implications for the scale of enterprise investment, it will also affect the organization and governance of the process of resource allocation within

the firm. Who are the key decision makers in allocating resources to innovative investments? On what basis do they make their investment decisions? How do they coordinate investment decisions across the firm? What capabilities do they have for making these decisions? How do their incentives relate to those of participants in the learning process and to organizational objectives?

These questions only hint at the plethora of issues that are raised by a consideration of the organizational dimension of firm-level innovation. Economists have also highlighted other important characteristics of the innovation process, such as its cumulative character and inherent uncertainty; their implications for resource allocation also require consideration in any comprehensive economics of innovative enterprise. Scholarly analysis of these issues is, as yet, uncommon. Indeed, studies of the internal processes that companies use to allocate financial resources to any type of investment, not just innovative ones, are rare (for exceptions, see Bower 1970; Burgelman and Sayles 1986).

### 9.2.2.2 Finance, Innovation, and the Industry

Empirical studies have confirmed the importance of cross-industry variation in certain basic characteristics of innovative activity. Industries vary not only in the distribution of innovative activity between entrants and incumbents at a point in time but also over time as measured by the stability or turbulence of these populations' shares of innovative inputs and outputs (for a summary, see Malerba, Ch. 14, this volume). Sectoral differences in innovative activity have important implications for resource allocation.

p. 247 To the extent that entrants dominate innovative activity, for example, the question of how they get access to the resources that they require to innovate is crucial. While the financing of *de novo* entry is relevant here, empirical studies have shown that entrants are not necessarily new ventures; entry also occurs through spin-offs ↵ from established firms as well as diversification by incumbent firms in other industries. As a result, understanding how the resources of existing firms are reallocated, by decision makers in those firms or the employees that leave them to establish new ventures, is also important.

If the heterogeneity of entrants' origins generates a range of questions about resource allocation, so too do other types of observed variation in sectoral patterns of innovation. Industries display important differences in competitive interactions among firms. If we focus on the relationship between entrants and incumbents, for example, we find that some entrants compete directly with incumbent firms for customers whereas others build an innovative strategy based on licensing arrangements or joint ventures. Gans, Hsu, and Stern contrast biotechnology, where joint ventures and alliances between entrants and incumbents are common, with hard disk drives, where entrants confronted incumbents in head-to-head competition in product markets (Gans, Hsu, and Stern 2000: 3). These differences have implications for the type and amount of investment that needs to be made by innovative firms. They affect the extent to which firms are involved in different business activities, such as production or marketing, and, more generally, the costs for different players of organizing themselves to innovate.

Industries differ not only in the competitive interactions among firms but also in terms of the relationships between firms and other industry actors. Competitive firms may have relationships with their suppliers and customers as well as universities and governments (local, regional, national, and international) that exert an important influence on their allocation of resources (Malerba, Ch. 14, this volume). In the early stages of the development of the US software industry, for example, the federal government played a crucial role in supporting the education and training of large numbers of software engineers (Mowery and Langlois 1996). As a result, many start-up companies were able to enter the industry as viable competitors without having access to the resources that would have been necessary if they had undertaken this effort on their own. Similarly, in the US biotechnology industry the citation patterns for patents show a major reliance by private companies on public science in their innovative activities with similar implications for their capacity

to economize on the resources that they needed to invest to become players (McMillan, Narin, and Deeds 2000).

In addition to intersectoral variation, the relationship between finance and innovation may vary over time within a given industry. Industries in which entrants drive innovation in one era may change over time to a structure in which innovation becomes more incremental in character and is dominated by incumbent firms, as in the automobile industry. Cases of the opposite trend also exist, as incumbent-dominated industries face waves of innovation-led entry—the development of biotechnology within pharmaceuticals is a good example. The characteristics of the enterprises that require finance, the sources of finance on which they rely, and the implications of these financial arrangements for innovation, are likely to differ significantly as a result of these evolutionary changes.

p. 248 We must also consider the possibility that the direction of causation goes in the other direction, from finance to innovation. As far as the distribution of innovative activity between entrants and incumbents is concerned, for example, we could ask whether incumbent firms dominate because they are more innovative or because entrants are too financially constrained to compete with them. Conversely, when entrants dominate is it because they are more innovative than incumbents or because a ready, and even excessive, availability of financial resources allows them to do so?

The latter question is the subject of two related studies of the hard disk drive industry. In an article called “Capital Market Myopia,” William Sahlman and Howard Stevenson (1985) argue that venture capitalists and the stock market massively over-invested in the industry during the period from 1977 to 1984 with negative consequences for financial returns and for innovation. However, another study of the disk drive industry claims that the diagnosis of capital market myopia is suspect in long-term perspective. Bygrave, Lange, Roedel, and Wu accept that many players in the disk drive industry failed but they argue that the survivors ultimately enjoyed sufficient commercial success to justify the financial bets that were made on the industry (Bygrave, Lange, Roedel, and Wu 2000: 17).

These two studies hint at the potential of analyses of the joint influence of finance and innovation on industry evolution but they are exceptions (see also Carpenter, Lazonick, and O'Sullivan 2003). The extent to which labour is reallocated from incumbent firms to entrants through spin-off activity has attracted some recent interest (see e.g. Klepper 2001). To date, however, the relationship between the allocation of financial resources and industrial patterns of innovative activity has been largely ignored.

### 9.2.2.3 Finance, Innovation, and the Economy

Contemporary economists have developed several approaches to thinking about the economics of innovation at the level of the economy, that is, to the relationship between innovative activity and economic development. One perspective, that of techno-economic paradigms, builds directly on Schumpeter's work on business cycles (for a summary, see Freeman and Louçã, 2001). A second approach—the national systems of innovation framework—has been developed over the last 25 years to explain comparative-historical patterns in economic development (Nelson 1993).

p. 249 Both approaches share a commitment to the Schumpeterian emphasis on the structural composition and evolution of the economy in analyses of economic development. The two approaches differ, however, in their attention to resource allocation. In the national systems of innovation literature, the process through which labor and capital are allocated to innovation processes is rarely discussed even ↵ when its significance is recognized (Nelson 1993: 13). In contrast, the literature on techno-economic paradigms has long been concerned with the interaction between innovative activity and the allocation of labour (Freeman 1977). With the recent publication of *Technological Revolutions and Financial Capital: The Dynamics of Bubbles*

and *Golden Ages* by Carlota Perez (2002), the relationship between finance and techno-economic paradigms has also received systematic treatment.

Perez follows Schumpeter in placing technological revolutions, that is, “clusters of radical innovation forming successive and distinct revolutions that modernize the whole productive structure,” at the heart of her theory. However, her concept of a revolution places much greater emphasis on the diffusion of innovation than is found in Schumpeter's work.<sup>4</sup> She also emphasizes, to a much greater degree than Schumpeter did in his work on business cycles, that the effects of technological revolutions go far beyond their economic impact to include “a transformation of the institutions of governance, of society and even of ideologies and culture” (Perez 2002: 24–5).<sup>5</sup>

Perez's analysis of the interaction between the financial and productive system is also more comprehensive than that of Schumpeter. While the latter focused primarily on the role of the financial system in funding an initial burst of innovative investment, Perez characterizes the ways in which the financial system may be involved in the productive system throughout the life cycle of technological revolutions. She argues that the relationship between the financial and productive sectors alters as the economy moves from one stage of the life cycle to another.

Perez's book represents an important contribution to our understanding of finance and innovation. Not surprisingly, given its originality, it suffers from certain limitations that will need to be addressed in future work. In particular, systematic empirical support for some of the key arguments that she makes about the role of finance in funding technological revolutions is not provided.<sup>6</sup>

However, a similar Schumpeterian analysis of finance and technology is found in several recent empirical articles by Boyan Jovanovic and his co-authors on the relationship between the development of the stock market and technological revolutions in the US economy from the late nineteenth century until the present (Jovanovic and Greenwood 1999; Jovanovic and Rousseau 2001; Hobijn and Jovanovic 2001). For example, Jovanovic and Rousseau (2001) compare and contrast the implications of the IT revolution with that of the “electricity-era” technological revolution for the US stock market. They show that the transition periods from founding to listing on the stock market, from incorporation to listing and from first product or process innovation to listing were shorter at the beginning and end of the twentieth century than in the intervening years, and argue that the explanation for this pattern can be found in the characteristics of technological change (Jovanovic and Rousseau 2001: 336).

## 9.3 Innovation and the Economics of Finance

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In the previous section, I emphasized that economists of innovation, as a general rule, have not been greatly inspired by Schumpeter's concern with finance and innovation. For a long time, there was a general neglect of the interaction between finance and the real economy in other branches of economics. However, in recent years that has begun to change.

Theoretical developments in the field of corporate finance have stimulated interest in the interaction between enterprise finance and investment. In the literature on economic growth, the influence of endogenous growth theory has led economists to consider how and to what extent the financial system might affect the rate and process of economic growth. As a result, some of the issues that are now being explored by economists, such as the characteristics and importance of venture capital as a source of finance, as well as the financing of R&D-intensive firms and new ventures, are of direct interest to those concerned with the economics of innovation. However, empirical research has lagged theoretical development and the evidence that does exist is often ambiguous even on some of the basic theoretical propositions that have



been advanced. Moreover, there are serious limits to the dominant conceptual approaches employed by financial economists for understanding the relationship between finance and innovation.

### 9.3.1 The Microeconomics of Enterprise Finance

From the late 1970s, there was a major shift in theoretical research on corporate finance based on the economics of information. A whole new set of theories of corporate finance emerged that took as their starting assumption the importance of “information asymmetry”<sup>7</sup> as a determinant of enterprise finance. One impact of the growing influence of information economics on corporate finance was a transformation in the way financial economists thought about alternative sources of finance. There was a move away from the rather simple cost–benefit analyses of different sources of finance that had been inspired by the work of Modigliani and Miller (1958). Comparisons of alternative sources of finance increasingly considered their implications for the information, incentives and control of different economic actors.

p. 251 These developments stimulated fresh treatments of old distinctions among alternative sources of finance; traditional comparisons between debt and equity and bank- and market-based finance, for example, were conceptualized in new ways based on the economics of information (Allen and Gale 2000). Moreover, sources of finance that had previously received little attention from financial economists ↪ attracted interest given what appeared to be their distinctive characteristics from an information–economics perspective; the best example is the burgeoning literature on venture capital.

An article by William Sahlman (1990) pioneered in using the logic of asymmetric information as the foundation for a theory of venture finance. Sahlman identified several different mechanisms, commonly employed in the process of venture capital investing, that he claimed venture capitalists used to overcome the problems of financing ventures in the presence of asymmetric information. In subsequent work, other scholars delved further into the roles played by these mechanisms, such as staging, compensation, monitoring and control of investee companies, and exit, in the relationship between venture capitalists and their investee companies (for a summary of this research, see Gompers and Lerner 1999).

p. 252 Important theoretical advances have been made in analyzing the economics of alternative sources of enterprise finance empirical analysis has lagged behind. Even basic evidence on the relative importance of different sources of enterprise finance, such as internal and external sources of funds, as well as alternative sources of external funds like banks, stock and bond markets, and venture capitalists is modest (see Box 9.1 for a summary history of the US venture capital industry). More ↪ challenging questions, such as whether enterprises choose alternative sources of finance for the reasons posited by financial economists or whether their use of these sources has the implications for performance that theories of enterprise finance suggest, remain largely unexplored (Rajan and Zingales 1995: 1421).

### Box 9.1 Venture capital in comparative–historical perspective

The United States is the country most closely associated with a professional venture capital industry. Although individuals and families in the United States, as in most industrial economies, long have used their private fortunes to fund new ventures, the US venture capital “industry” began with the founding in 1946 of American Research and Development (ARD) for the finance of new ventures. ARD was founded in Boston by members of the local investment community, as well as professors and administrators from MIT. With the expansion of federally funded research at MIT during World War II, the principal sources of ARD's deal were the federally funded laboratories at Harvard and MIT. By far its most successful deal was its 1957 investment in a new firm founded by Kenneth Olsen of MIT's Lincoln Laboratory, the Digital Equipment Corporation (DEC) (Rosegrant and Lampe 1992: 72, 110–14).

The enormous success of ARD's investment in DEC—when the computer firm went public in 1966 ARD's original investment of \$70,000 was valued at \$37 million—generated huge interest in venture capital in the financial community. By that time, a new breed of financiers had emerged out of Silicon Valley's high-technology enterprises. Successful entrepreneurs like Fairchild's Eugene Kleiner and Don Valentine reinvested the capital that they accumulated in promising local start-ups and brought cash and technical skill, operating experience, and networks of industry contacts to the ventures they funded. Silicon Valley's venture capitalists were heavily involved with their ventures, advising entrepreneurs on business plans and strategies, helping find co-investors, recruiting key managers, and serving on boards of directors (Saxenian 1994: 39).

Several regulatory changes contributed to the further expansion of the US venture capital industry in the 1980s and 1990s. Particularly important were a series of legislative initiatives in the late 1970s that made venture capital a much more attractive investment option: the capital gains tax rate was reduced from 49.5 to 20 per cent and it became much easier for pension funds to invest in venture capital partnerships. There was a major increase in the flow of money into the US venture capital from then on (see fig. 1.1 in Gompers and Lerner 1999: 7). Historical trends in investments and disbursements by the industry displayed considerable volatility, with major boom–bust cycles recorded in the 1960s, the 1980s and again in the late 1990s/early 2000s.

Investments by the US venture capital industry were highly concentrated by sector. For the period from 1965 to 1992, four industries—office and computing machinery, communications and electronics, pharmaceuticals, and scientific instruments—accounted for 81 per cent of all investments by the US venture capital industry. The relative importance of these sectors changed considerably over time; office and computing machines became less important over time whereas the drugs sector increased its share of venture capital investment. In the 1990s, especially in the second half of the decade, Internet-related investments were estimated to account for 70 per cent and 75 per cent of all venture capital investments in 1999 and 2000 respectively (Venture Economics).

Measured as a share of gross economic output, the US venture capital industry is the largest in the world. The venture capital industries of other countries enjoyed considerable growth in the 1990s; for the EU as a whole, for example, venture capital investment increased from 0.04 to 0.12 per cent of GDP for the period from 1989 to 1999 with Belgium, Sweden and the Netherlands recording particularly strong expansion (Table 9.1). Nevertheless, even more rapid growth in the US venture capital industry during this period meant that it actually increased its lead over other countries, particularly in early-stage investment activity by venture capitalists.

The growing influence of information economics stimulated another body of theoretical analysis of enterprise finance, encouraging interest in the long-neglected interaction between the financing and investment behavior of enterprises. Since information asymmetries between enterprises and financiers made external finance more expensive for companies than internal finance, *ceteris paribus*, enterprises with access to substantial liquidity from internal sources would invest more than enterprises that have to resort to external finance.

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There is now a substantial body of empirical evidence that suggests that “liquidity constraints” matter to capital investment (for a summary see Hubbard 1998: 199). However, serious methodological concerns have been raised about these studies. Particularly controversial has been the common practice of imputing the importance of liquidity constraints from the sensitivity of a company's investment to its cash flow. Some scholars claim that “investment-cash flow sensitivities provide no evidence of the presence of financing constraints” thus calling into question the validity of the empirical results reported in this literature (Kaplan and Zingales 2000; Fazzari, Hubbard, and Petersen 2000).

**Table 9.1** Venture capital and early-stage investment as a percentage of GDP

Country	VC Investment as percentage of GDP		Early-Stage Investment as percentage of GDP	
	1989	1999	1989	1999
Austria	0.01	0.03	0.006	0.007
Belgium	0.05	0.26	0.015	0.093
Denmark	0.01	0.05	0.009	0.019
Finland	0.01	0.11	0.003	0.057
France	0.05	0.12	0.009	0.039
Germany	0.01	0.13	0.004	0.051
Greece	n.a.	0.06	n.a.	0.017
Ireland	0.05	0.09	0.002	0.048
Italy	0.02	0.05	0.002	0.014
The Netherlands	0.05	0.25	0.006	0.096
Portugal	0.02	0.05	0.004	0.008
Spain	0.02	0.09	0.009	0.018
Sweden	0.02	0.19	0.004	0.113
United Kingdom	0.13	0.20	0.023	0.020
EU	0.04	0.12	0.008	0.036
US	0.11	0.59	0.027	0.056

Source: Christofidis and Debande, 2001, p. 20, p. 23.

Theories that posited that the influence might go in the other direction, that the characteristics of enterprise investment might influence enterprise finance, were also developed. One stream of literature posited a relationship between the types of activities in which enterprises invested and their financial

behavior. Another suggested that characteristics of the investing enterprise, for example, its stage of development, mattered to the way it was financed.

p. 254 In analyses of the influence of enterprises' activities on their financing, R&D investments attracted particular attention since they were deemed to create acute information asymmetries between corporate managers and financiers (Bah and Dumontier 2001: 675; Himmelberg and Petersen 1994; Hall 2002). The main implication that has been drawn from such analyses is that the gap between the costs of financing R&D investment from internal and external sources should be greater than  $\hookrightarrow$  for other forms of investment. Therefore, R&D-intensive firms should be more inclined than other firms to rely on internal funds to finance their investments. Moreover, financing constraints arising from imperfections in capital markets should have a much greater impact on R&D, than other, investments (Hall 2002; Carpenter and Petersen 2002: F55). Recently, some scholars have suggested that these arguments apply not just to R&D investments but to all investments in hightechnology industries (see Bank of England 2001: Annex, 81–5).

Empirical analyses of the relationship between finance and R&D are primarily analyses of the links between cash flow and R&D expenditures. The common finding of these studies is that R&D investment is indeed positively correlated with cash flow (for a summary see Hall 2002). However, these studies are subject to the same methodological criticisms as the empirical work on liquidity constraints and capital investment to which we have already referred, and until these issues are resolved we cannot be confident of their findings.

Financial economists have also begun to analyse whether the characteristics of investing firms might matter to their financing behavior. Particular attention has been paid to a company's stage of development and the concept of a “financing growth cycle” is now widely used to characterize the challenges for firms as they evolve from new venture to going concern highlighting once again the extent of informational asymmetry involved (Berger and Udell 1998: 622). Perhaps the most straightforward implication of this type of analysis is that firms at earlier stages of the cycle, such as start-up companies, are likely to have difficulties raising external finance. As a result, they should be more heavily dependent on insider finance than firms at later stages of development.

Once again, however, empirical research has not kept pace with theoretical developments. The evidence that has been compiled, moreover, does not provide clear support for some of the most basic propositions advanced in the theoretical literature. In this regard, Berger and Udell highlight two findings from their empirical analysis which seem particularly surprising. The first is that the funds provided by the principal owner are more important as the firm gets older than at early stages. Second, their evidence suggests that finance from insiders never outweighs that provided by outsiders even for the youngest firms (Berger and Udell 1998: 625).

p. 255 The two streams of literature on the influence of investment characteristics on enterprise finance—the one on characteristics of the investments being made and the other on the characteristics of investing firms—have recently been brought together in research on the financing of small firms making R&D, high-technology, or technology-based investments, often referred to as technology-based small firms (TBSFs). Theoretical models from the “new” corporate finance predict that these firms will be much more tightly constrained by their own internal resources in financing their investment than other firms. As yet, however, the jury is out on whether even this basic proposition is borne out by empirical evidence. As a recent report by the Bank of England concluded: “the evidence from such studies is  $\hookrightarrow$  conflicting on the key issue of whether TBSFs face greater difficulties in accessing finance than SMEs [small and medium enterprises] in general” (Bank of England 2001: 83).

### 9.3.2 Financial Systems and Economic Growth

Contemporary growth theory, in recognizing the importance of technological change for economic growth, echoes Schumpeter's emphasis on the importance of innovation as the primary impetus for the process of economic development. Moreover, whereas Schumpeter emphasized the importance of financial systems in fueling innovation and, therefore, economic development, the idea that the development and structure of a country's financial system might have implications for its economic growth was treated with skepticism or indifference by most macroeconomists in the second half of the twentieth century. In recent years, however, there has been a major increase in interest in the relationship between financial development and economic growth, a trend that is usually attributed to the influence of endogenous growth theory in macroeconomics. A variety of theoretical articles model the mechanisms through which the financial system might affect long-run growth. Empirical studies have also been undertaken, primarily based on large-scale crosscountry regressions, to analyze the relationship between financial systems and economic growth.

Most of these studies of finance and growth seek to relate the level of development and structural characteristics of the financial system to aggregate economic activity. Consistent with the dominant approach taken in neoclassical growth theory, economic development is understood as an undifferentiated quantity generated by an aggregate production function. As a result, contemporary analyses of finance and growth make no reference to the structural composition and evolution of the economy and, therefore, ignore what Schumpeter regarded as the essential characteristic of the process of economic development, that is, its lumpiness over time and across sector.

However, there are a few exceptions to the general rule. Rajan and Zingales (1998) differentiated among industries in terms of their investment and financing behavior, arguing that their financial requirements are technologically determined:

there is a technological reason why some industries depend more on external finance than others. To the extent that the initial project scale, the gestation period, the cash harvest period, and the requirement for continuing investment differ substantially between industries, this is indeed plausible. (Rajan and Zingales 1998: 563)

p. 256 Their main hypothesis is that industries that are more dependent on external finance should grow faster in countries with more developed financial markets. Several other studies have followed Rajan and Zingales in discriminating among industries in terms of their demand for finance. Some of them go further to consider whether financial structure—notably whether a financial system is market- or bankbased—matters to the development of different industries (Beck and Levine 2002; Demirgüç-Kunt and Maksimovic 2002; Carlin and Mayer 2003).

The central implication of this disaggregated approach to the relationship between finance and growth is that the economic impact of financial systems may be reflected not only in aggregate rates of economic growth but also in the differential development of particular industries. Differences in the growth trajectories of particular industries will in turn be reflected in variations across country in the composition of economic growth; sectors favoured by a nation's financial system will become more and more prominent in the economy over time while other, lessfavoured sectors will languish or fail to develop. However, as yet, the task of analyzing the relationship between financial systems and the structural evolution of the economy has not been treated in any detailed way in these studies.

## 9.4 A New Agenda for Research on Finance and Innovation

Contemporary research in economics has a long way to go before it can help us to understand the relationship between finance and innovation. In the economics of innovation, that relationship has been largely neglected though questions about resource allocation are latent in existing research. In financial economics, some scholars have begun to explore concerns that are directly relevant to the study of finance and innovation, but financial economists have been more effective at generating new theoretical arguments than adducing empirical evidence to support them.

In principle, there is a good case for integration of the two fields as a route to new insights on the relationship between finance and innovation. However, there are serious limitations of the dominant theoretical approaches that financial economists employ for analyzing the process of economic change. Moreover, barriers of mutual ignorance and, more fundamentally, methodological difference, make such integration unlikely. Collaboration between economists of innovation and historians of finance is a much more promising path to a better understanding of the relationship between finance and innovation. These scholars share a commitment to history as a technique of economic analysis which is crucial given that the essential processes that need to be understood in analyzing the interaction between finance and innovation are historical processes.

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### 9.4.1 Finance Theory and the Dynamics of Economic Change

Important weaknesses of the research of financial economists become evident when we bring the literature on the economics of finance into contact with what we know about the dynamics of innovation. As a result, it is doubtful that, left to their own devices, financial economists will ever develop a satisfying understanding of the role of finance in the process of innovation. In the microeconomic literature, the main problem is the centrality of the concept of asymmetric information in theories of enterprise finance. It is true that analytical space for the “real” economy was created by incorporating this concept; so long as one could argue that a real phenomenon led to important asymmetries of information, financial economists were willing to take it seriously in theories of enterprise finance. However, the versatility of the concept hints at its limitations.

One problem is that it has been invoked in a rather casual manner without much in the way of proof of the extent of asymmetries of information or their importance in influencing economic relationships. For the case of R&D investments, for example, one typically finds an assertion that they are subject to acute problems of asymmetric information. Yet, why should we assume that investors have less information about the likely success of pharmaceutical companies' R&D efforts than the factors that determine the productivity of a new automobile plant?

More fundamentally, it is not clear that privileged access to information by some economic actors is the major determinant of the challenges for enterprises in financing such investments. When making innovative investments, a more important challenge than asymmetric information is the fundamental uncertainty that characterizes the relationship between investments and their outcomes. In an environment characterized by fundamental uncertainty, the crucial problem is not that one person knows something whereas another does not; rather the challenge to decision making is ignorance, the fact that nobody really knows anything.

Uncertainty in this sense is different from the concept as it is used in neoclassical economics (Arrow and Debreu 1954; Arrow 1974) where the main concern is with parametric uncertainty.<sup>8</sup> The environment in which economic decisions are made is characterized as a set of mutually exclusive but collectively

exhaustive possible states of the world. In such a world, one that is closed and deterministic, rational decisions based on probabilistic estimates are a reasonable basis for action.

p. 258 When uncertainty is fundamental, as it is when innovation occurs, economic agents are uncertain not just about which possible state will obtain but about which ones are even possible. In making innovative investments, therefore, there are really ↪ no objective guidelines for making decisions or for resolving disputes. So how does anyone act under these circumstances? How do innovative investments ever get made given the uncertainty that surrounds them?

Questions about decision making under fundamental uncertainty are further complicated by the fact that the process of innovation reveals new, possible states of the world (Kline and Rosenberg 1986: 297–8). In other words, the uncertainty inherent in innovation unfolds as the process evolves. As a result, the future state of the world cannot be defined until it is discovered through the process of innovation (Rosenberg 1994: 53–4). Through involvement in that process, or close familiarity with it, decision makers learn and, as they do so, their perceptions of the possibilities and problems of innovative investment change. There is no reason to assume that, in altering their perceptions based on new information, decision makers necessarily move closer to some kind of truth. To the contrary, they are likely to make many mistakes in interpreting what the information that they have implies for the challenges and opportunities of innovation.

Economists who take seriously the fundamental uncertainty that surrounds innovative investment have tended to emphasize the importance of subjective judgements, based on perceptions and belief systems, for decision making. They have also suggested that, in reacting to the unfolding of the uncertainty inherent in innovation, decision making is experiential as well as interpretative. Financial economists tend to overlook the basic cognitive characteristics—ignorance, learning and error—of resource allocation and the mechanisms that allow enterprises to make commitments of resources to innovative activity notwithstanding the challenges of doing so. To date, in analyzing enterprise finance, financial economists have emphasized rationality, indeed a rather limited and static concept of rationality, to the exclusion of the subjective and experiential dimensions of decision making. While rational analysis may well feed into the process of innovative resource allocation, it cannot dominate it.

If financial theory is of limited use for understanding the cognitive challenges associated with innovative investment, it provides no help at all in dealing with other important features of firm-level innovation such as its organizational character. Notwithstanding the important progress that has been made in microeconomics in conceptualizing the economics of the firm, theorists of corporate finance have failed to embed their analyses in a substantive theory of the firm (Zingales 2000). In fact, many financial economists remain wedded to the idea of the firm as a nexus of contracts and reject the notion of firms as organizations that have a logic that is distinct from that of markets.

p. 259 As far as the macroeconomic literature is concerned, its main problem for understanding the relationship between finance and growth is that it conceptualizes it in a rather mechanical way. Most of the models used in this literature treat economic growth as if it was generic across the economy and over time. Typically, they make no allowance for variation and change in the organizational and ↪ institutional contexts in which financial resources are allocated and employed to facilitate economic growth. Instead, the relationship between finance and growth is understood in terms of the influence of the quantity of finance provided and, to a lesser extent, the price at which it is supplied, on the “amount” of economic growth.

In contrast, research on innovation and technological change suggests the central importance of the context in which these processes occur to their impact on productivity and economic development. It is for this reason that Gavin Wright, a prominent economic historian, has recently exhorted economists to embrace “[a] conception of technology that is historically-contingent and institutionally specific” (Wright 1997: 1562). From this perspective, research on finance and innovation must devote greater attention to the role



that contextual factors play in shaping financial relationships. Who gets financial resources, when they get them, how they use them and other factors that can only be identified by making qualitative distinctions among enterprises, time periods, and investments, are likely to be more important than the overall quantity of financial resources that is invested in an industry.

Recent studies that incorporate sectoral differences in their analyses of finance and growth tend to overlook the importance of these contextual factors. They assume that given characteristics of technologies matter to the scale and timing of enterprise investment and, as result, to enterprise demand for finance. However, even if we take technological characteristics as given, a range of variables, such as the balance between entrants and incumbents and, more generally, the competitive structure of the industry, defines the context that shapes the relationship between technology, investment requirements and financing needs. Moreover, the relationship between technology and finance is likely to change within industries over time, in part because technological characteristics of industries evolve, but also since the intervening variables that determine their relationship to finance also change.

### 9.4.2 The Possibilities and Problems of Integration between Fields

Some of the weaknesses of financial economics for dealing with the relationship between finance and the dynamics of economic change could be overcome, at least in principle, through closer integration with research on innovation. There is some recognition of this fact within financial economics. One prominent scholar in the field, Luigi Zingales, has been quite explicit in his call for “new foundations,” notably a more sophisticated analysis of the firm, for the study of enterprise finance. Particularly interesting from my perspective is the fact that he emphasizes the importance of “a theory of entrepreneurship” for understanding how firms innovate (Zingales 2000).

p. 260 Economists of innovation, in turn, can learn from research in finance. In part, their having greater contact with financial economists might stimulate a general interest in finance among them but the specific details of existing research can also be a source of useful insights. For example, the recent attention by financial economists to the relationship between stages of an enterprise's development and its financing requirements could be fruitfully incorporated by economists of innovation.

If the only barrier to intellectual integration was lack of familiarity with each other's work then it would be relatively easy to overcome. However, ignorance of another's field of inquiry typically conceals deeper barriers. In addition to theoretical differences described above, methodological differences pose a formidable barrier to the integration of research on finance and innovation.

Perhaps the most important methodological obstacle to cross-fertilization between the fields of innovation and finance is the different priorities that they assign to history in economic analysis. In recognition of the importance of change over time in the process that they study, economists of innovation often describe themselves as “evolutionary economists” and they typically assign considerable importance to historical research in their economic analysis. In their empirical work, they tend to emphasize the importance of qualitative variations across the economy and over time in innovation and technological change. They are often skeptical of theories of innovation and economic development that are abstracted from the historical contexts and emphasize the importance of “reasoned history” and “history-friendly models” (Freeman and Louçã 2001; Lazonick 1991; Malerba et al. 1999).

In contrast, most financial economists neglect the fact that capitalism is an evolutionary process. Equilibrium analysis overwhelmingly dominates theoretical research to the neglect of the historical origins and evolution of economic behavior. In empirical research, quantitative analysis is the norm and attention to qualitative variations within the economy and over time is modest. It is hardly surprising, therefore, that limited attention is paid in theoretical or empirical research to the historical development of the financial

system, the structural evolution of the economy or change over time in the relationship between the financial system and the real economy.

It seems unlikely that such methodological differences can be overcome in the foreseeable future. A more promising avenue to intellectual progress on the relationship between innovation and finance, therefore, is for economists of innovation to collaborate with financial historians. Evolutionary economists have already had direct experience of the value of a shared methodological commitment to historical analysis in facilitating intellectual exchange through their collaboration in research on technological change with historians of technology, labor, and business. Similarly fruitful exchanges are likely to result from interaction with economic and business historians who study the history of financial systems. Indeed, there are already some promising signs of research in this direction (see e.g. Lamoreaux and Sokoloff 2004).

## 9.5 Conclusion

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What are the priorities in new research on finance and innovation? It is widely recognized that the paucity of, and flaws in, existing empirical research on the financial system are major barriers to economic analyses of its role. The dearth of evidence is a problem even if we focus on contemporary patterns of financial demand and supply. When we look to historical data, the holes in our understanding of these patterns are even more gaping (Levine 2003; O'Sullivan 2004a, b; Zingales 2003).

It is true that patterns of financial demand and supply by enterprises, firms, and economies serve only as background evidence for more specific empirical questions about the relationship between finance and innovation. In an ideal world, scholars who are primarily interested in researching that relationship could compile these data from readily available sources. However, the current, rather dire, state of empirical research on patterns of financial demand and supply mean that this option is not available.

It is hard to see, therefore, how substantial progress in our understanding of finance and innovation can be made unless scholars who are interested in the subject are willing to contribute to the compilation of these data so that basic empirical questions can be addressed. At a minimum, we need evidence that allows us to identify variation and change in the historical patterns of financing by firms, industries, and nations. We also need to understand long-term trends in the supply of resources by different financial institutions. For example, how important has the stock market been as a source of finance for corporate investment in different economies at various times? What types of industries and firms did it finance during different periods? Are there marked differences in the characteristics of firms and industries funded by bond markets and banks? (For the weaknesses of existing empirical research on these questions, see O'Sullivan 2004a, b.)

Only when we have identified these basic patterns in financial demand and supply can we hope to understand how they are related to the dynamics of economic change. For example, in the case of a particular industry we might ask how patterns of financial demand and supply are related to the balance between incumbents and entrants in innovative activity. For an economy, the relationship between financial patterns and changes in the structure of the economy, such as the shift from manufacturing to services, are clearly relevant. For understanding these types of interactions between finance and the dynamics of economic change, empirical studies that treat the demand for, and supply of, finance as characterized primarily by quantity and price can only take us so far. Detailed case studies are needed to generate insights on the qualitative dimensions of these interactions that could then be used to illustrate, enrich and perhaps confront some of the implications that can be drawn from quantitative studies.

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Of course, progress in the analysis of finance and innovation cannot be made based on empirical research alone. At a minimum, empirical studies need to be theoretically informed in terms of the questions that they pose. Therefore, a certain amount of conceptual development on the relationship between finance and

innovation will be necessary to facilitate empirical studies on the subject. One promising route to new ideas is the further development of the implications for resource allocation of observed characteristics of innovation at the level of the firm, the industry and the economy along the lines discussed above. However, theoretical research needs to go farther than an analysis of the implications of the characteristics of innovation for finance to consider how the structural characteristics and evolution of the financial system influence innovative activity in the real economy.

## Notes

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1. The author gratefully acknowledges the helpful critiques and suggestions that she received from the participants in the various workshops organized to produce this book. She would like to thank Jan Fagerberg, Bronwyn Hall, Bill Lazonick, David Mowery, and Richard Nelson for the particularly detailed comments that they provided on earlier drafts of this chapter as well as Ron Adner and Bruce Kogut, her colleagues at INSEAD, for their helpful suggestions.
2. The term “enterprise finance” is used herein to refer to research on corporate and venture finance.
3. The other major exception is Alfred D. Chandler. From a theoretical perspective, much of his work can be seen as contributing to a similar concept of the firm as that of Penrose. Indeed, in recent years, in reflecting on the general implications of his research, Chandler has tended to use the language of organizational learning (see e.g. Chandler 1992).
4. This is true of most of the contemporary literature on techno-economic paradigms (Freeman and Louçã 2001: 149)
5. In *CSD*, however, Schumpeter was centrally preoccupied with the social and political, as well as the economic, implications of changes in the characteristics of the innovation process.
6. Indeed, Perez explicitly portrays her book as “a ‘think-piece,’ the spelling out of an interpretation, with enough illustrations to strengthen the case and stimulate discussion” (Perez 2002: xix).
7. In economics, the term “information asymmetry” is used to refer to a situation in which one economic agent has more information than another about a task that affects both agents' welfare.
8. For general discussions of the difference between structural or radical uncertainty and parametric uncertainty, see Loasby 1976; O'Driscoll and Rizzo 1985; Langlois 1986; Shackle 1992.

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