



Uncertainty in the Austrian Theory of Capital

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Abstract. This paper is based on the traditional Austrian Theory of Capital which deals with expected values of future returns of investments over various periods of time. The longer the time period that elapses between the beginning of a production process and its end, the higher the (expected) productivity must be due to positive time preferences of individuals. This paper focuses on the uncertainty of future returns and on uncertainty preferences, instead. Based on the Hayekian idea of the dispersion of knowledge in society, it will be shown that there is a systematic relationship between the structure of capital and uncertainty. This result will be derived for a production process characterized by complete vertical integration and one which is not completely vertically integrated. The distinction between these two settings is crucial, if one accepts the distinction between an individual and a social period of production and the planning horizon which are introduced in this paper.

Key Words: capital theory, uncertainty, period of production, capital structure, productivity

JEL classification: B13, D21, D24.

Introduction

Problems of capital and finance are reduced to trivial questions of market allocations by the specific set-up of microeconomic theory. As inputs are transformed into output instantaneously, the proceeds of the output can be used to pay for the inputs necessary.¹ The only relevant constraint the firm face is that the optimal output must be feasible—it must be within the bounds of the production possibility set. This constraint is fully defined by technology. Standard microeconomic theory, therefore, focuses on marginal productivity and the marginal rate of technical substitution, but neglects the financial aspects of production, such as funding initial set-up costs, fixed and working capital, and investments to expand the production possibility set. The concepts of time and uncertainty (modeled in terms of additive subjective probability, i.e. as risk) receive some attention in models of complete markets and/or sequential trade.² However, their structure implies that capital and finance do not receive sufficient attention in standard micro-economics. Therefore, the income-effect is not included in the Slutsky-equation of the firm. The stability- and uniqueness-conditions of the general equilibrium are all based on the characteristics of the demand functions.³

Austrian Capital Theory (ACT) has focused on the concept of time as early as 1871, when Menger's Principles were first published. In the first section I will outline the basic concepts of ACT. Distinctions between the individual and the social period of production, as well as the planning horizon will be made. In the second section the prominent role of uncertainty in Austrian Economics will be emphasized. Both dimensions of time and uncertainty featured equally prominently in Menger's Principles. The role of uncertainty

in ACT will be analyzed in the forth section based on the distinction between production processes which are characterized by complete vertical integration and those which are not. Building up on Hayek's analysis of the consequences of the dispersion of knowledge in society, I will demonstrate that the structure of capital is inherently related to the dimension of uncertainty. The last section concludes and points at further research topics in the ACT.

1. Foundations of Austrian Capital Theory

The Austrian School of Economics emphasizes the structuralist interpretation of economic phenomena. Streissler (1969) defines its research agenda predominantly via this approach. He refers to structuralist as "... the explicit development of aspects of dispersion, of variances as such, *the focus on heterogeneity as central theoretical vision. . . . the decomposition of aggregates in order to increase the explanatory content* which can be derived by viewing the aggregates as undifferentiated wholes." (Streissler (1969:241); original emphasis).

Menger accentuates the decomposition of the entire spectrum of goods with regard to the causal relation of each good to the satisfaction of individual desires. This relation can be a direct one—as is the case for first order (or consumer) goods—or an indirect one—as is the case for higher order goods, leaving the goods-character unaffected.⁴ Menger's Law then states that the value of goods depends solely on the expected value consumers attach to the corresponding first order goods. The values of higher order goods are derived from them on the basis of their marginal (value) product.⁵ The value of a good is not directly related to the value and/or quantities of higher order goods used in its production.⁶ That implies that production costs are completely irrelevant ex-post. Current and past prices can at best serve as starting points to forecast future prices. These forecasts of future prices of lower order goods can, in turn, influence the current prices of the higher order goods required in their production.⁷ The Austrian theory of value is therefore forward looking.

The purpose of entrepreneurial activity is to adapt the existing structure of production (including technology, quantity and quality of capital, distribution of ownership) to expected changes in the economic conditions, and to exploit subjective profit opportunities, which arise from differences between the expected future prices of lower order goods and their production costs. These arise, if the prices of higher order goods do not reflect the subjective, discounted expectations of their future marginal value product. Therefore, production is always a decision under uncertainty and based on subjective expectations.⁸ As these can be different among entrepreneurs, their success can be markedly different too.⁹

The distinction between risk and uncertainty becomes blurred when one relies on additive subjective probabilities assigned to all possible states of the world to model uncertainty (as opposed to risk).¹⁰ Such interpretations assume that (i) all possible states are known to the individual a-priori, (ii) the individual is in a position to make the required reliable assignments which can be represented by an additive probability distribution, (iii) the individual is indifferent with respect to different degrees of ambiguity, vagueness (or reliability and confidence) associated with different assignments. Non of these restrictive assumptions are compatible with the notion of uncertainty. In order to deal with subjective attitudes towards uncertainty, the notion of uncertainty aversion is adopted.¹¹ Dow and Werlang (1992:200)

develop a measure of it as the deviation of the sum of the assigned subjective probabilities from additivity. They stress that “the nonadditive prior represents both the presence of uncertainty and the agent’s aversion to it.” (Dow and Werlang 1992:199). They also argue that nonadditive priors in the same possible events (which are not necessarily all known to the individual) can be ranked according to their degree of uncertainty aversion based on the deviation from additivity, i.e. the larger the deviation, the larger the uncertainty aversion. The nonadditivity of probabilities does not refer to objective probabilities, but to individual assignments of subjective probability. The individual wants to retain the possibility to assign further subjective probabilities to hitherto unknown events without necessarily changing the assignments already in place. An alternative interpretation holds that individuals systematically undervalue probabilities (relative to the Bayesian probabilities)¹² associated with ambiguous events and overvalue those associated with unambiguous ones.¹³ The weights reflect the individual’s confidence in the respective probability assignments. As the uncertainty associated with an investment project increases,¹⁴ the sum of the nonadditive priors decreases, the deviation from unity increases and, consequently, the expected utility falls.¹⁵ In order to maintain a certain level of expected utility as uncertainty increases, the uncertainty averse individual demands a compensation (an uncertainty premium), an increase in the pay-off in at least one state of the world with a positive subjective probability, to compensate for the fall in the sum of the probabilities.

The misunderstanding that the order of goods is based on objective criteria has led to confusion in the past, and has laid the foundation for unjustified criticism by Marshall, Knight, Sraffa and many others, who have accused ACT of circularity. Any particular good can be employed in more than one stage of production and, in many cases, serve as a consumption good as well.¹⁶ Coal can be a first order (consumption) good, if it is used by a consumer to heat his/her apartment. If it is utilized in the production of steel the very same commodity is a good of a higher order than the steel which it aids to produce. There is no objective criterion on which this distinction can be based.¹⁷

The demand for a higher order good depends upon the various ways it can be employed in production. The order of goods is therefore an order of demand functions which comprise different determinants at each stage of production. The demand for a particular good (e.g. coal) in stage i depends on the demand for a sub-set of goods of order 1 to $(i - 1)$. The sub-set consists of all goods of order 1 to $(i - 1)$, which are produced by employing the good (e.g. coal) under consideration as an input (directly or indirectly). At the same time the demand for the particular good in stage i is completely independent of the demand functions of all goods of order $(i + 1)$ —it is independent of the historical costs of its inputs. This implies that the demand for all goods is a function of the expected demand for goods of order 1—consumption goods, which again corresponds to Menger’s Law.

ACT also implies that goods of higher order are complementary, since the transformation of one higher order good into one of lower order regularly requires one or more other higher order goods.¹⁸ This transformation is a process requiring time. The concept of time is central to the Austrian Theory of Capital. But the relevant notion is not an objective one. The average period of production is a technological ex-post concept and should therefore be irrelevant for ACT. Böhm-Bawerk’s attempts to reduce capital theory to the time dimension alone has earned him the criticism of Menger.¹⁹ The emphasis must be placed on the ex-ante,

subjective concept of the *planning horizon* (or the expected production time). This concept dates back to Menger (1950:152) and was stressed by Streissler (1973:170) as well as Kirzner (1996:43).

In a recent paper Samuelson (2001) reiterates the traditional critique of Böhm-Bawerk's objective concept of an average period of production. The average period of production is defined as the ratio of the sum of all time periods embodied in the different, heterogeneous labor inputs divided by the number of units of all labor inputs. By numerical examples he shows that there can be no objective measure of the average period of production, which would ensure that this average period of production is always inversely related to the real rate of interest. An analysis based on the technological ex-post concept of the average period of production cannot perceive the problems of capital theory that arise in connection with the intertemporal character of Menger's Law (i.e. time discounting, the order of goods, expectations, knowledge and uncertainty). The prominent role of the average period of production might thus offer an explanation for the neglect of the systematic relation between the order of goods and uncertainty in ACT. Furthermore, Samuelson fails to distinguish between capital deepening, capital widening and more round about methods of production that take into account the role of complementarity and indivisibility of higher order goods in production plans.²⁰ Lewin (1999:64) presents a short history and summary of various strands of criticism of the average period of production. He dismisses the average period of production as an inherently problematic construct.²¹

Böhm-Bawerk (1921:118) introduced the average period of production mainly to be able to cope with three problems: (i) Inputs that might have been produced a very long time ago in the past lengthen the (historical) objective period of production almost infinitely. By relating the amount of labor that is associated with these early inputs to the entire sum of labor inputs, their influence on the average period of production becomes negligible. This problem does not arise in the subjective concepts employed in this paper as it is the result of a technological ex-post concept which includes the first act of production that would eventually be related to any input in current production in the relevant period of production. (ii) In order to distinguish between more or less capitalistic production processes—even if both cover equal social periods of production but employ different inputs and different technologies—Böhm-Bawerk's average period of production increases as more units of labor date further back in history. Based on this concept, he attempts to compare the degree of capitalism across different production processes and technologies. (iii) In order to compare degrees of capitalism across different economies or across history, Böhm-Bawerk has to incorporate characteristics of the stage of capitalistic development, within which the individual entrepreneur chooses the optimal production plan into his analysis.²²

This paper steers clear of such comparisons and consequently avoids the technological ex-post concept of the period of production. Its focus is restricted to subjective microeconomic concepts (e.g. entrepreneurial decision, individual and social period of production, individual planning horizon)²³ and a systematic relationship between the order of goods and uncertainty.²⁴ It abstains from discussions of, and comparisons across different objective technologies and from the aggregation over capital goods, entrepreneurs or production processes.

1.1. *The Individual and the Social Period of Production, and the Planning Horizon*

The individual period of production is defined as the time that is expected to elapse between the beginning of a production process of order i and the expected date of sale for the final good. This can be of the order i or of any order j (for $1 \leq j < i$) depending on the degree of vertical integration. The individual period of production cannot be measured objectively. It is endogenous to the investment decision—it might be shortened by an increase of inputs—and subject to uncertainty itself, as the endpoint cannot be estimated with certainty.²⁵ Generally, I refer to the individual period of production at the profit maximizing input-output combination. The social period of production is defined as the time that elapses between the initiation of a production process of the good of order i and the final sale of the related consumption good of order 1. The two subjective and microeconomic concepts of the individual and the social period of production are identical only in cases of complete vertical integration.

The beginning of a production process is the moment in which (1) an entrepreneur identifies a profit opportunity due to a difference between his expectations concerning the current opportunity costs of some good of order i and expected future value(s) of the relevant goods of order j ($i < j \leq 1$); and (2) decides to incur opportunity costs in order to exploit the profit opportunity.²⁶ Consequently, it is a subjective notion as well, further obstructing any attempts to measure the period of production objectively.

The beginning of the (subjective) planning horizon is independent of the time it took to produce the inputs which are about to be employed in the production process. To induce individuals with positive time preference rates to engage in investments that require a longer individual period of production, their expected rate of return must be higher *ceteris paribus*. The individual period of production does not necessarily span the entire period until the final first order good is sold to the consumer.²⁷ In the absence of complete vertical integration it is usually the case that the individual period of production of a good of higher order is much shorter than the related social period of production. The individual period of production of a good of order i can end as soon as the good is sold to the producer of a good of order $(i - 1)$ as an input. But that does not mean that the planning horizon ends at that point, because—as we can infer from Menger's Law—the value of the good of order i is a function of the expected value of the relevant first order goods as these are a relevant factor in the valuations of good i by the producers of a good of order $(i - 1)$.

The fundamental propositions of the Austrian Theory of Capital can be summarized as follows:

- (1) Goods differ with regard to their causal connection to the satisfaction of human needs—they are of different order.
- (2) The value of a good of higher order is derived from the (expected) value of the relevant subset of first order goods—Menger's Law. The relevant subset consists of all first order goods with a direct or indirect causal relation to the higher order good under consideration.
- (3) It is an empirical fact (axiom) that humans discount more distant consumption more heavily.

- (4) The time that elapses between the beginning of a particular production process and its end is a monotonically increasing function of the order of the goods involved.
- (5) More roundabout methods of production—which involve goods of a higher order than less roundabout methods—must yield a higher (expected) return.

The distinction of an individual and a social period of production poses some interesting problems for ACT, if the production process is not completely vertically integrated: In those cases the individual and the social period of production are not identical. The individual period of production is not connected to the order of goods: The individual period of production of a good of order i is not necessarily longer than the individual period of production of a good of order j (for $j < i$). The individual period of production of a good is a characteristic of the available production processes, the application rate and of strategic decisions related to the degree of vertical integration but not a characteristic of its goods-character. Since the order of a good is independent of its physical characteristics, the order of goods is not related to the individual period of production. An entrepreneur discounts only over the period that he ex-ante expects to elapse between his investment and the receipt of his revenue. That period is identical to the individual period of production. Therefore, discounting over the entire social period of production is only possible, if the production process is completely vertically integrated. Otherwise, the discounting of all individual entrepreneurs whose individual periods of production sum up to the corresponding social period of production has to be taken into consideration. The market rate of interest, its term structure, the related expectations, and the expected effects on the demand function for the relevant goods of lower order determine the combined effect of the individual acts of discounting along the production process.²⁸ The planning horizon and the social period of production are both related to the goods-character. For a particular production process, they are both monotonically increasing functions of the order of goods.

Furthermore, problems of dispersed knowledge in society are hardly mentioned in ACT. That seems to imply that complete information is assumed throughout any capital theoretic argument in Austrian Economics.²⁹ Although it is only future (expected) values that are to be considered, neither uncertainty nor incomplete knowledge receive much attention in the arguments. The decomposition of the aggregate “goods” has to be based on two dimensions: time and uncertainty. “Again and again Menger stresses the *time dimension* of goods and the amount of uncertainty this entails.” (Streissler (1973:163); original emphasis). Over the past one hundred years, ACT was centered solely on the time dimension—the (social) period of production.

Following Böhm-Bawerk (1921:112) I will rely on the empirical regularity that the social period of production and the planning horizon increase with the degree of roundaboutness of a production process and that the production of higher order goods is associated with a longer social period of production and a longer planning horizon than the production of lower order goods (at given technology—or a given stock of knowledge³⁰—shared by all). The following sections stress the importance of uncertainty in the Austrian School of Economics and attempt to introduce the dimension of uncertainty into ACT by systematically relating uncertainty to the structure of goods.

2. Uncertainty in Austrian Economics

According to Machlup six ideas are widely believed to have been central to the Austrian School of economics prior to WWII:³¹ (a) methodological individualism, (b) methodological subjectivism, (c) marginalism, (d) emphasis on subjective value in price theory, (e) opportunity costs, and (f) time structure of consumption and production. As the Austrian School is one of the foundations of modern neoclassical economics it is not surprising that many of the above ideas are now more or less accepted within the economics profession.

In due course of the planning debate in the 1930s, it became apparent that the mainstream of economic theory—which was supposed to be securely rooted in Austrian ideas—arrived at very different conclusions about the possibility of social planning than the Austrians did. In the light of the results by Oskar Lange the Austrians noticed how far away the mainstream had drifted from their own ideas in the 1920s. In two papers Hayek (1937, 1971) emphasized the central role of knowledge and uncertainty in economics. In order to distinguish themselves from the mainstream further characteristics of Austrian economics were included in Machlup's list: "... (g) markets (and competition) as processes of learning and discovery, and (h) the individual decision as an act of choice in an essentially uncertain context ... It is these latter ideas that have come to be developed in, and made central to the revived attention to the Austrian tradition ... " (Kirzner (1987:149)).³²

Nevertheless, uncertainty was already central to Menger's *Principles*. The quality and quantity of the output of a particular production process is subject to uncertainty for two reasons: (i) not all the relevant factors influencing the relation between inputs and output of a particular production process are known, (ii) not all of the relevant factors can be controlled completely.³³ Streissler (1973:161) highlights that Menger's theory is an information theory emphasizing uncertainty. Menger stressed that the value of higher order goods is essentially dependent upon expected values of lower order goods.³⁴

In his *Principles* Menger (1950:160) assigns four essential functions to entrepreneurial activities: (a) gathering the necessary information about the economic situation, (b) ensuring the efficiency of the production plan by the appropriate calculations, (c) actually undertaking the task (the necessary act of will), and (d) undertaking the supervision of the production processes to ensure its efficiency. He explicitly excludes risk (or uncertainty) bearing from this list which could be an explanation for the apparent discrepancy between Menger's emphasis on expected values and his neglect of the systematic relationship between the order of goods and uncertainty in capital theory.³⁵

Borch (1972:33) offers another explanation by arguing that Menger deliberately neglected uncertainty with regard to expected demand. As he assumed the *Principles* were but the first part of a more complete series, he focused on a fundamental theory of price formation. The more advanced issues—e.g. uncertainty with regard to expected demand—were supposed to be discussed in the parts following the *Principles*.

Yet, another explanation is that the Austrians implicitly assume perfect information in ACT. Due to the fact that the importance of information, knowledge and its dispersion in society are stressed by Menger and Hayek, this argument does not seem particularly

appealing. Böhm-Bawerk (1889:258) explicitly discusses the issues of expected value, the certainty equivalent and the risk premium at some detail. Any choice between different uses of a certain higher order good is based on discounted current value units ('detaxierter Gegenwartswert' Böhm-Bawerk 1889:325) but risk (or uncertainty) has no bearing on the real rate of interest apart from a risk premium that has to be deducted from the nominal rate just like transaction costs and the rate of depreciation (Böhm-Bawerk 1889:261, Hennings 1997:116). The relation between the order of a good and productivity is related to time alone and not to risk (or uncertainty). The systematic relationship between the structure of capital and the risk premium is not touched upon at all.

Hayek (1941:330) stresses that the stock of capital largely depends on the correct foresight of the entrepreneur regarding the future situation in a world of uncertainty. Furthermore, he briefly discusses how capitalists should treat extraordinary profits due to risky undertakings (1941:332) and the consequences of savings exceeding, or falling short of expectations (1941:344). Notwithstanding, Hayek (1941) does not pay attention to the relationship between uncertainty and the structure of capital. Kirzner (1996:43, 22, 39, 40) emphasizes the forward looking nature of the planning horizon, the role of expectations concerning the plans of producers of lower order goods as well as consumers and the potential for entrepreneurial error. In his discussion of the latter he briefly mentions that as time passes the evidence of error becomes clearer.³⁶ Nonetheless, also Kirzner (1996) fails to develop the systematic relationship between uncertainty and the order of goods.

In contemporary Austrian Economics there are some instances where the role of risk (or uncertainty) in ACT is briefly discussed.³⁷ Garrison (1994:120) points out that the interest rate consists of three components: an underlying time discount, an inflation premium, and a risk premium. He further emphasizes that Hayekian capital theory focused on the first component only. Garrison (1994:122) develops the fundamentals of a business cycle theory based on policy induced market failure to allocate risk according to individual risk preferences.³⁸ In due course of his argument, he postulates that long-term investment is inherently more risky than short-term investment as a shorter planning horizon leaves less room for (negative or distorting) policy surprises. However, the systematic relation between the order of goods and uncertainty is not further discussed. Cowen (1997) develops a risk-based theory of the business cycle that emphasizes increases in the risk of the economy as a consequence of a decline in the real interest rate. One of the fundamental assumptions underlying his theory is the relationship between the length of the planning horizon and the risk associated with an investment project.³⁹ Although Cowen mentions information-sensitivity in his argument concerning this assumption, he does not develop a systematic relationship between the order of goods and uncertainty. Lewin (1997a, 1997b) points out that time and the presence of uncertainty are essentially interrelated in the notion of subjective time preference so that the pure time preference theory of interest incorporates implications of uncertainty even if the expected future income stream under consideration is not subject to uncertainty itself. This however is something else than recognizing the systematic relationship between the structure of capital, the value of capital and the uncertainty of the expected future income stream derived from final consumption via the stages of production.

3. The Introduction of Uncertainty in ACT—A Systematic Relationship Between the Stages of Production and Uncertainty

3.1. Complete Vertical Integration

In the case of complete vertical integration the production time a particular producer faces equals the entire expected time period that elapses between the initiation of the production process and the sale of the related consumer good(s). The individual period of production is equal to the social period of production as well as the planning horizon. The discounted present value of the proceeds from this sale depend on the discount factor and the expected market revenue. It is therefore necessary to form expectations of the future demand of a particular consumption good.⁴⁰ Since the value of any particular good is ultimately derived from the value of first order goods, the primary source of uncertainty is the variation of future consumption demand for the relevant first order good(s). In addition to forecast the aggregate (industry) demand curve, entrepreneurs need to derive the individual demand curve they face based on estimates of the supply conditions and prices of other sellers.⁴¹

The process of adjustment can be interpreted as a process of learning.⁴² Hayek (1937) illustrates the point by the use of an example: Entrepreneurs invest to produce a certain number of houses and at the same time consumers save in order to be able to afford these houses in the future. Their plans are coordinated by continuous adjustment based on relative prices. The ex-ante equilibrium of plans—i.e. all plans are mutually consistent—which is established by relative prices has to be continuously adjusted to changes in the exogenous data on which the underlying individual decisions are based. After each change of data relative prices adjust and individual plans are adapted to the new environment. The longer the planning horizon under consideration the more changes of data occur and the more frequently individual plans have to be adapted. The notion of a tendency towards (ex-post) equilibrium, therefore, is an empirical one referring to the final outcome of the co-ordination of individual plans.

“It can hardly mean anything but that, under certain conditions, the knowledge and intentions of the different members of society are supposed to come more and more into agreement or, to put the same thing in less general and less exact but more concrete terms, that the expectations of the people and particularly of the entrepreneurs will become more and more correct.” (Hayek 1937:45).

Expectations cannot become more and more correct unless one interprets Hayek from a probabilistic point of view: Correctness is not a continuously scalable attribution—expectations can either be correct or they can be incorrect. But the confidence of individuals in the subjective probability assignments can increase over time. Equilibrium is reached when expectations tend towards a situation where all ex-ante plans are ex-post consistent. In equilibrium everybody possesses all the relevant knowledge. How knowledge is communicated and acquired is one of the central research agendas in economics, according to Hayek (1937:50).

Possible changes in the technology of production of lower order goods and potential shifts of the market supply curve due to changes in the supplies of the relevant competitors

constitute further dimensions of uncertainty: The expected profit associated with the underlying profit opportunity changes.

Prima facie, there is no systematic relationship between the different dimensions of uncertainty: (1) variations in the demand for the relevant first order good(s), (2) potential changes in technology, and (3) potential changes in the market supply curve for the higher order good under consideration. Furthermore, there is no systematic relationship between the variations of the different variables over time.

Consequently, the level of uncertainty related to demand of a higher order good is an increasing function of the time period s —the planning horizon at given levels of capital specificity.⁴³ If specificity changes, the pattern of correlation of different uses of the capital good might affect the volatility of its demand, i.e. a decrease in specificity at a given pattern of correlation between the valuations of the output of different uses of a good of order i at the stages j ($j < i$) will reduce the uncertainty associated with the production of a good of order i . But specificity is neither systematically related to the order of a good, nor are its effects on uncertainty unambiguous as they depend on the pattern of correlation between the valuations of the output of different uses of a good of order i at the stages j ($j < i$).

Uncertainty is systematically related to the structure of capital. Given that individuals are uncertainty averse, any investment project that requires a more roundabout method of production will require a higher marginal utility of expected return not only to compensate for the additional time, but in the case of uncertainty averse individuals, also for the additional uncertainty involved.

3.2. *Vertical Disintegration*

If the theory of production is understood as a subjective theory, it must be modeled as a decision theory. In the absence of vertical integration, the relevant production time—a particular producer faces—is the time that is expected to elapse between the beginning of a production process of order i and the expected date of sale of the final good of the i th order. This is the period between investment and realization of revenues, i.e. the period over which entrepreneurs have to discount expected revenues and returns. The individual period of production is shorter than the social period of production. In the case considered here (complete vertical disintegration) it spans a single stage of production only. The relevant expectations have to concern the demand for the i th order good as an input in the production of a good of the $(i - 1)$ th order the producer under consideration will face.

“But due to the causal connections between goods, the value of goods of higher order goods is not measured directly by the expected importance of the final satisfaction, but rather by the expected value of the corresponding goods of lower order.” (Menger 1950:152).

Apparently, the value of a good of order i is a function of consumption demand for all the first order goods which are eventually produced by employing the i th order good as an input. Therefore the planning horizon spans the entire social period of production from the first time a particular producer purposefully interferes⁴⁴ to the time in which he expects

the demand for the relevant first order goods to be realized and all uncertainty with respect to it to be resolved. If feasible, his expectations concerning the value of the relevant first order goods could enhance his ability to anticipate decisions and valuations of producers of lower goods, i.e. they could decrease the ambiguity and increase the confidence of expectations (i.e. of the non-additive subjective probabilities) of the producer of a good of order i concerning the valuations of good i by the producers of a good of order j ($j < i$).⁴⁵ The planning horizon spans the entire social period of production. As in the case of complete vertical integration the uncertainty associated with the underlying demand for the relevant first order good increases with the length of the planning horizon, i.e. with time. For the moment I shall assume that it is only systematically related to time, but not the order of the good (i.e. the number of intermediary producers of lower order goods) under consideration.

In addition to the planning horizon and its relation to uncertainty concerning the expected future demand for the relevant first order good(s), there are two more dimensions of uncertainty which are related to the order of goods. Even if one knew the future demand for all relevant first order goods with certainty, the derivation of demand for the i th order good of a specific producer is not trivial. Due to (1) product and process innovations the optimal input ratio might change at any stage j ($1 \leq j < i$) and below. Alternatively, even if production technologies remain unchanged, (2) producers at stages j ($1 \leq j < i$) might restructure their supply chains, and (3) the market share of producers at stages j ($1 \leq j < i$) might change independently of the demand for the relevant first order goods (e.g. due to activities of their competitors).

Potential shifts of the market supply curve due to changes in the supplies of the relevant competitors of the good of order i are not systematically related to order of the good. The level of uncertainty associated with such potential changes is a monotonically increasing function of time. The individual period of production, though, is not necessarily longer for a good of order i than for a good of order j ($1 \leq j < i$), if the production process is not characterized by complete vertical integration.

The variations related to the four different dimensions of uncertainty—namely (1) potential changes in market demand for the relevant consumption goods over time, and (2) potential changes in the optimal input/output relation due to product and process innovations at stages j ($j < i$), (3) potential changes of the structure of the supply chain at stages j ($1 \leq j < i$), and (4) changes of market share of producers at stages j ($1 \leq j < i$) independently of the demand for the relevant first order goods—are not systematically related to each other.

Consequently, the level of uncertainty of the demand for the good of order i is a monotonically increasing function of the planning horizon as well as a monotonically increasing function of the order goods at given levels of capital specificity. It is an increasing function of the *time* interval (the planning horizon but not of the individual period of production) over which expectations have to be formed. But it is also a monotonically increasing function of the *order* of the good under consideration due to an increase in the number of intermediaries and potential changes in the demand for higher order goods at each stage of production j ($1 \leq j < i$). We can, therefore, conclude that uncertainty and the structure of production are systematically related. Investment projects that involve a more roundabout method of

production (in terms of both, the planning horizon and the order of goods)⁴⁶ must yield a higher marginal utility of returns if individuals are uncertainty averse.

A further line of reasoning relates uncertainty and the structure of production: The assumption that the uncertainty associated with the underlying demand for the relevant consumption goods is a function solely of time, but otherwise independent of the order of the good shall now be relaxed. As stated above, this assumption implies that the quality of estimates of consumption demand is not related to the stage of the production process or to the planning horizon directly. The quality of estimates of the future expected consumption demand is related to the stages of production only via the dimension of time. But this would mean that the necessary information on which to base the various estimates is available to everybody in society. Furthermore, it would be so at the same marginal costs. Every producer has to be informed about the relevant consumer goods markets. This is a very restrictive assumption for two reasons: Information about a specific consumer good market is more readily available to those who are operating in that market, and secondly, the higher the order of a good the harder it is to define the markets of relevant first order goods. In many cases it is impossible to know which first order goods are produced directly or indirectly by means of the higher order good i under consideration. Even if it were technically feasible to list all first order goods which are produced by using as an input a special higher order good i , this information would be very costly to collect.

“The peculiar character of the problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess.” (Hayek 1971:17).

The producer of the higher order good i does not and cannot possess all the relevant knowledge to estimate the future demand for all relevant first order goods. This division of knowledge has not received the appropriate attention in ACT although it is one of the central problems in economics, according to Hayek (1937:50).

It is the distinct advantage of an economic order based on decentralized planning that the producer of the higher order good i does not have to gather all the relevant information by himself. It is sufficient, if it is communicated to him.

“... in a society in which many people collaborate, this planning, whoever does it, will in some measure have to be based on knowledge which, in the first instance, is not given to the planner but to somebody else, which somehow will have to be conveyed to the planner.” (Hayek 1971:18).

It follows from Menger’s Law that changes in the estimates of the demand for the relevant first order goods affect the expectations for the expected demand for, and the value of a higher order good. The relevant knowledge, though, depends on particular circumstances of time and space. And even to those who deal in first order goods directly, their future value is subject to uncertainty, because all they might know with certainty is based on experience about the past and present and they, nevertheless, have to estimate the future

value of the first order goods they offer. At each stage producers add to the variation and the uncertainty related to the incomplete knowledge of the particularities of time and space due to subjective interpretation of the individual observations and the signals received. As the number of stages—across which the relevant knowledge of time and space has to be conveyed—increases the price signals become noisier and, thus, the signal extraction problem becomes more twisted. This line of reasoning adds two more dimensions of uncertainty: The knowledge of (5) the composition of the relevant set of first order goods and (6) of the relevant circumstances of time and space to form expectations of prices of the relevant first goods is conveyed to producers of higher order goods at decreasing quality. As this knowledge becomes the fundamental factor in forming expectations of the prices producers of goods of the $(i - 1)$ are willing to pay, the uncertainty associated with these expectations increases with the order of goods.

It is important to distinguish between the following dimensions of uncertainty concerning expected future consumption demand: (i) Uncertainty that is the consequence of incomplete knowledge about the composition of the set of relevant first order goods and the factors underlying their (expected) value as observed by those who convey that information to the entrepreneur of stage i . (ii) Factors that change consumption demand over time, i.e. after it has been conveyed to the next stage in the production process—e.g. changes of consumer preferences, product innovations or macroeconomic shocks. While (i) is related to the order of goods, (ii) is related to the individual period of production which is independent of the order of goods in the case of complete vertical disintegration.

One might argue that statistical information about consumption demand is readily available in any industrialized country. Furthermore, this information is usually very cheap, because it is provided by public institutions (e.g. national statistical offices, ministries etc.) for public use. The very nature of statistical aggregates, though, renders them useless for most of the investment decisions under consideration, as they abstract from all changes within the aggregate. Since entrepreneurs need to estimate the consumer demand for the goods which influence the future expected value of the higher order goods they produce, any data on aggregate consumer demand might be helpful but by no means sufficient.

Prima facie, the variations resulting from the signal extraction problem, with respect to the demand for the relevant first order good(s), are neither systematically related across stages of production, nor to the other four dimensions of uncertainty in the case of complete vertical disintegration.⁴⁷

If one accepts that the value of a higher good is deduced from the future expected value of the relevant first order goods and that this knowledge is—to a large extent—only available to those who deal in first order goods, one must also accept that the uncertainty associated with the expected future demand for a good of order i at the stage $(i - 1)$ is increasing in the order of goods, since it increases (1) with uncertainty associated with the demand for the underlying first order goods which in turn increases over time as the length of the planning horizon increases, *and* with the order of goods as (2) potential changes in the optimal input/output relation due to product and process innovations at various stages of production, (3) potential changes of the structure of the supply chain at stages j ($1 \leq j < i$), (4) potential changes in the market shares of producers at stages j ($j < i$), (5) knowledge about the composition of the set of relevant consumer good(s), and (6) about the circumstances of time and space

to form expectations about their prices are directly related to the order of goods. Therefore, uncertainty aversion implies that the expected marginal utility of returns on investments in more roundabout production processes must be higher than in less roundabout ones (at given levels of capital specificity). In addition to compensate entrepreneurs for the opportunity costs of waiting, the premium must also include the compensation for the systematic increase in uncertainty.

Conclusion

The relevant concept in Austrian Capital Theory used to be the (social) period of production. But if the individual decision is to be central to the argument, one must focus on the individual period of production. In cases of *complete vertical disintegration*, this is the time period which is expected to elapse between the beginning of a production process of order i and the expected date of sale of the final good of the i th order. This is the time interval between the investment decision and the realization of returns. Therefore, this is the relevant period for discounting. So that the length of the social period of production is the result of combined individual discounting of producers at each stage of the production process. In cases of *completely vertically integrated* production processes, the social and the individual period of production are identical. The planning horizon is a subjective concept that spans the entire social period of production irrespective of the degree of vertical integration, because the value of any higher order good is derived from the value of the corresponding first order goods.

This paper introduced the systematic relationship between the order of goods and uncertainty to ACT. Based on the Hayekian arguments in the planning debate, it has been demonstrated that uncertainty is inherently related to the structure of capital. The fundamental propositions of the Austrian Theory of Capital (see pp. 10) have to be amended by the following propositions:

Complete Vertical Integration. (4a) The level of uncertainty of the demand for a good of order i is related to the expected value of future demand of the relevant first goods. It is a monotonically increasing function of the planning horizon (time)—at given levels of capital specificity. The dimensions of uncertainty are (1) potential changes in expected demand for the relevant first order goods, (2) potential changes in the technology used in production, (3) potential changes in the market supply curve (e.g. due to change in the production technology of competitors).

Vertical Disintegration. (4b) The level of uncertainty of the demand for the good of order i is a monotonically increasing function of the *planning horizon*, of time *and* the *order* of the good (at given levels of capital specificity). The uncertainty associated with the expected future demand for a good of order i at the stage $(i - 1)$ is increasing in the order of goods, since it increases (1) with uncertainty associated with the demand for the underlying first order goods which in turn increases over time as the length of the planning horizon increases, *and* with the order of goods as (2) potential changes in the optimal input/output relation due to product and process innovations at various stages of production, (3) potential

changes of the structure of the supply chain at stages j ($1 \leq j < i$), (4) potential changes in the market shares of producers at stages j ($j < i$), (5) knowledge about the composition of the set of relevant consumer good(s), and (6) about the circumstances of time and space to form expectations about their prices are directly related to the order of goods. The dimensions of uncertainty (2) to (6) are systematically related to the *order* of the good.⁴⁸

(5a) More roundabout methods of production—which involve goods of a higher order than less roundabout methods—must yield a higher expected return. In addition to compensate entrepreneurs for the opportunity costs of waiting, the premium must also include the compensation for the systematic increase in uncertainty.

In order to establish a systematic relation between the structure of capital and uncertainty, I only have to assume that individuals are aware of the *relative* dimensions of uncertainty across time or between different investment projects, i.e. that they are aware of their own relative planning horizons and/or the relative structures of production. Still, that does not imply that they know the order of the goods they are producing, let alone that the order of goods could be defined objectively.

How does the introduction of uncertainty influence the traditional arguments in the Austrian Theory of the Business Cycle? In a first attempt to analyze this question, Schmitz (1999) uses the model of a risk-averse bank to analyze the effects of changes in liquidity reserves⁴⁹ on the degree of relative risk aversion. The distribution of payoffs the bank faces, is assumed to be contingent on the loan rate. Under certain conditions, credit rationing results from the model. A decrease in the liquidity position of the bank results in an increase in the degree of relative risk aversion under the very same conditions. It is demonstrated that the Hayekian analysis can incorporate the dimension of risk as the effects of tightening of monetary policy and changes of bank expectations on bank lending are proofed to have identical signs. Further research has been mentioned above and incorporates Cowen (1997) and Garrison (1994). Beyond these first attempts probing this problem, further research needs to be initiated in this area.

Preliminary empirical evidence is presented in Schmitz (1999). Goods included in the wholesale and retail price indices commonly have the same physical characteristics. The variance of the wholesale price index usually exceeds that of the retail price index. The systematic relation between uncertainty and the order of goods provides a potential explanation. However, further empirical research is necessary.

The complete neglect of the structural relation between uncertainty and the order of goods as well as the dispersion of knowledge in ACT is inconsistent with the emphasis on these concepts which characterize the Austrian School of Economics.

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Notes

1. See Morishima (1992:27).
2. See Mas-Collel, Whinston, and Green (1995:694).
3. See Varian (1992:395).
4. See Menger (1950:57).
5. See Menger (1950:162–165).
6. See Hayek (1941:89).
7. See Mises (1966:336).
8. See Lachmann (1956:15).
9. See Lachmann (1956), Hoppe (1997), and Lewin (1999:119).
10. I am indebted to Carlo Zappia for drawing my attention to non-additive probability theory and its potential role in Austrian Economics. For an account of the development of the theory, its relation to Austrian Economics and further references see Basili and Zappia (2000, 2002). The following short discussion draws mostly on these papers as well as on Dow and Da Costa Werlang (1992) and Epstein and Wang (1994).
11. Throughout the paper I will assume in addition that the individuals are risk neutral or risk averse.
12. For two mutually non-exclusive sets of events A and B (the probabilities of the sets of events normalized and monotone with the objective probabilities $P(A \cap B)$ and $P(A \cup B)$ given) the uncertainty averse individual assigns the subjective probabilities $P(A) + P(B)$ according to $P(A) + P(B) \leq P(A \cap B) + P(A \cup B)$ rather than $P(A) + P(B) = P(A \cap B) + P(A \cup B)$ as in additive (Bayesian) statistics, if the individual is uncertain with respect to the exact values of $P(A)$ and $P(B)$ (see Dow and Werlang 1992:203).
13. See Basili and Zappia (2002:9).
14. In a setting of subjective uncertainty an “increase in uncertainty” (i.e. in comparisons of uncertainty across projects) is shorthand for an increase in the dimensions along which uncertainty prevails, e.g. changes in the number of time periods in which different states of the world can materialize. That does not imply that individuals know the number of states that can materialize in each dimension, nor does it necessarily mean that they know all the dimensions. In order to establish a systematic relation between the structure of capital and uncertainty, I have to assume that individuals are aware of the relative dimensions of uncertainty across time or between different investment projects, i.e. that they are aware of their own relative planning horizons and/or the relative structures of production. However, that does not imply that they know the order of goods they are producing, let alone that the order of goods could be defined objectively.
15. See also Shackle (1942:79).
16. See Böhm-Bawerk (1889:322).
17. See Menger (1950:58). A typical consumption good becomes a second order good as soon as the decision to buy it is dominated by the plan to resell it on the second hand market. This is more obvious in cases of real estate demand where a well functioning “second hand” market exists. The very same house can be purchased in order to live therein, or to speculate on a rising price due to expected excess demand in the future. The physical characteristics are completely unchanged, but the determinants of the demand functions are different. The distinction between goods of different order can only be based on these purely subjective determinants.
18. See Hayek (1941) and Lachmann (1956:82).
19. See Streissler (1973:169).
20. See also Lachmann (1956:82–84).
21. Hayek (1941:76) calls the average period of production unnecessary and misleading. See also Hennings (1997:136) who argues that under additional assumptions a concept of a period of production can be defended in Böhm-Bawerk’s capital theory. But he also stresses that this concept is not a *conditio-sine-qua-non* for ACT. See also Kirzner (1996:77) for a subjectivist critique.
22. Lachmann (1956:79) compares Böhm-Bawerk’s theory of the division of capital to Smith’s division of labor and argues that both are to be interpreted as theories of economic progress.
23. See also Kirzner (1996).
24. It does not attempt to derive objective measures of the individual, the social period of production or the planning horizon, nor do its arguments rely on such objective measures. See also footnote 14.
25. See Lewin (1994:212, 1999:64) and Garrison (1990:136).
26. See also Garrison (1990:136).

27. See Kirzner (1996:38).
28. See also Garrison (1985:170).
29. Kirzner (1996:37) explicitly discusses entrepreneurial error in ACT.
30. See Lachmann (1956:79). The assumption applies to production processes at the same stages of capitalistic development rather than complete mutual knowledge in the Kirznerian sense which would make entrepreneurial activity futile.
31. See Machlup (1981:6) and Kirzner (1987:148).
32. See also Mises (1966:105) and Kirzner (1997:69).
33. Also Böhm-Bawerk (1889: 258) and Lewin (1997a) emphasize that—at the time of the investment decision—the individual decision maker can only operate based upon expectations of input and output values.
34. See Menger (1950:150) and Böhm-Bawerk (1889:316).
35. “After what I have said, it will be evident that I cannot agree with Mangoldt, who designates ‘risk bearing’ as the essential function of entrepreneurship in a production process, since this ‘risk’ is only incidental and the chance of loss is counterbalanced by the chance of profit.” (Menger (1950:161); original emphasis). Throughout this paper, the term risk will be used in discussing authors that do not explicitly distinguish between risk and uncertainty (especially representatives of the Austrian School) without judging the semantic content. Sometimes authors discuss uncertainty but refer to risk premiums at the same time.
36. See Kirzner (1996:40).
37. In addition outside ACT, Foss et al. (2002) highlight the implications of heterogeneous capital and uncertainty for the theory of the firm. But they, too, fail to recognize the systematic relationship between their two lines of argument.
38. Legislative action and policy innovation distort the perception of risk bearing by lenders and induce borrowers to engage in excessive risk taking. This leads, initially, to an economic boom that turns into a bust as soon as the actual losses reveal the actual risks born by the lenders. Garrison identifies the Depository Institutions Deregulation and Monetary Control Act of 1980 and the federal deficit of the 1980’s as major distortions to the allocation of risk in the US economy (for details see Garrison (1994)).
39. Other assumptions include that investment implies greater risk than consumption; a decrease in the interest rate will increase risk for each investor which translates into an increase in aggregate risk; riskier investments are associated with higher expected returns (at least in equilibrium); exogenous increases in real economic risk of investment will reduce investment (see Cowen (1997:16)).
40. See Menger (1950:89).
41. See Arrow (1959:46).
42. See also Kirzner (1997:71).
43. For a discussion of specificity in capital theory see Böhm-Bawerk (1889:234), Lachmann (1956:12), Hayek (1941:251), Hennings (1997:132), and Lewin (1999:123).
44. The entrepreneur incurs opportunity costs to exploit a perceived (expected) profit opportunity.
45. However, the expected marginal costs of forming such expectations and the associated uncertainty are systematically related to the order of goods as I shall argue in subsequent parts of this paper.
46. Böhm-Bawerk (1921:118) assumes that the empirical regularities, that the social period of production and the planning horizon increase with the degree of roundaboutness of a production process and that the production of higher order goods is associated with a longer social period of production and a longer planning horizon than the production of lower order goods (at given technology) holds. This is not a particularly restrictive assumption as long as it concerns certain production processes of a particular first order good and assumes a given technology. It is, nonetheless, a restrictive assumption when one wishes to engage in comparisons across different stages of economic development in history or across production processes of different first order goods which involve stages of production of systematically different length. If the rankings of different production processes based on the number of stages or the social period of production/the planning horizon differ, one would have to consider the net-effect of the changes in both dimensions—time and the number of stages of production—on uncertainty. This, after all, is beyond the scope of this paper.
47. The other four dimensions of uncertainty in the case of complete vertical disintegration are potential changes of demand for consumption goods over time, changes of the optimal input-output ratio, changes in the production of goods of order j ($1 \leq j < i$), the restructuring of the supply chains of producers at stages j ($1 \leq j < i$), and changes in the market shares of producers at stages j ($1 \leq j < i$).

48. In the case of complete vertical disintegration, dimensions of uncertainty that are related to the individual period of production do not add systematically to the level of uncertainty of the demand for a higher order good. The individual period of production is not systematically related to the order of the good under consideration.
49. The focus on liquidity reserves is an approximation of the focus on central bank policy in the traditional models of Austrian theory of the business cycle.

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