

The Development of the Net Present Value (NPV) Rule – Religious Prohibitions and Its Evolution

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Abstract: This paper describes the development of the net present value (NPV) rule. Today, net present value is a globally accepted methodology for investment appraisal in companies. Compared to other management techniques, net present value was developed and popularised comparatively late. The ban on interest, especially on compound interest, in religion and philosophy is identified as a key obstacle to its development, since compound interest is crucial for calculating NPV. German scholar Gottfried Wilhelm Leibniz's work made an important contribution to its advance in financial theory and practice. His work was adopted especially in Germany during the 18th and 19th century, but criticism and the allegation of usury was still present. One century later the instrument was advocated by engineering economics with the main representative Wellington and Grant in the early 20th century. Nevertheless, the breakthrough in practice was slow, and the rule was only established as a management tool after World War II, where practitioners like the management consultant Dean played a key role.

Keywords: Investment, Net Present Value (NPV), Usury, Interest, Leibniz

JEL Classifications: B13, B26, B49, G31

1. The Basic Problem

Modern investment appraisal – be it the proposed purchase of a machine or the valuation of a potential acquisition target – is based on two fundamental principles (see, e.g. two of the most commonly used text books in business schools: Brealey, et al. 2013):

- (1) The net present value (NPV) rule is used for investment appraisal. With NPV, a project is measured according to its value rather than its costs. Companies should accept all projects with a positive NPV and decline all projects with a negative NPV. When budgets are limited, companies should choose the projects with the highest NPVs. NPV assumes the evident logic that a dollar today is worth more than a dollar tomorrow. Since the calculation must be based on forecasted cash flows, the risk that the planned cash flows will not be reached must be considered in the opportunity cost of capital.
- (2) Since there is a spread of possible outcomes for the future cash flows that a project generates, risk has to be considered in the calculation. The basic and evident logic is as follows: the riskier a project, e.g. measured by the spread of different possible outcomes, the higher the opportunity cost of capital must be.

Most of the modern investment calculation methods are based on these two principles. The discounting of cash flows is also the main principle in valuing companies or parts of companies. In all of these methods, the numerator represents cash flows or another financial performance indicator, whereas the denominator represents the time value of money and has the economic function of representing the best alternative use to the project being evaluated.

The aim of this paper is to show NPV's involvement by focusing on the religious prohibition of interest as an obstacle to the instrument's advancement and Leibniz's contributions that helped to develop the rule.

The paper is organised as follows: Section 2 describes the ban on interest, and particularly, frames the ban on compound interest through its historical background and as an explanation for the delay in NPV's evolution as a management technique, since compound interest is essential to calculate projects. Section 3 refers to early contributors in the development of NPV. Section 4 is dedicated to Leibniz's contribution to the development of NPV. Section 5 covers NPV's success in the late 19th century and its breakthroughs after World War II.

2. The Ban on Interest and Its Roots

Investment decisions or the valuing of companies is not a modern concept (see Braudel 1982, p. 437). As long as human beings have traded with each other, they have had to make investment decisions. The sale of assets or investments is also not new. The problem has therefore always existed, and human beings have always had solutions for it, at least in an implicit manner. The merchants of the Hanse collaboratively equipped ships, meaning that they faced the problem of valuing the various shares of the project. Every entrepreneur has had to consider whether or not to carry out an investment. While other concepts of modern management can be dated back to ancient times, modern investment appraisal was discussed later in history. One reason for not using NPV was the ban on interest (usury), which was mainly rooted in ancient philosophy as well as in most world religions. While in the beginning, usury meant the charging of interest at any rate, the modern meaning of charging an unfair and disproportionate rate (as defined, for example, in Webster 2013) evolved parallel to the gradual acceptance of interest (Persky 2007, p. 229).

Although the historic discussion about usury is rooted in giving and receiving loans and not in evaluating projects, there is a close connection between the two issues: In NPV, the interest rate is used as the opportunity cost of the capital. The opportunity that is implied is a financial investment in which the money is given to another person who is investing it in assets. Thus, the ban on interest on loans has a direct impact on using interest rates for other purposes such as investment appraisal.

2.1 Aristotle's view of interest

Although the Greek philosopher Aristotle (384–322 BC) was in favour of private property, he was against trading if it had the aim of profit-making. In his opinion, profit distracts human beings from a virtuous life, and profiting from the exchange of goods can only occur by harming one's partner. If people only exchange essentials they do not have access to, a profit should not occur (Starbatty 2006, p. 30). Money was accepted as an instrument for easing exchange, but money was not allowed to play any other role in business because it was not a vital commodity. The desire to gather only essential commodities has a natural limit, whereas the wish to have money is infinite (Pellegrin 1981); therefore, money is a problematic commodity. Money cannot earn profit by itself: '[F]or it has not its origin in nature, but by it men gain from each other; for usury is most reasonably detested, as it is increasing our fortune by money itself, and not employing it for the purpose it was originally intended, namely exchange. And this is the explanation of the name, which means the breeding of money. For as offspring resemble their parents, so usury is money bred of money.'

Whence of all forms of money-making it is most against nature' (Aristotle 1928, p. 1258b).

It is important to mention that in ancient Greece, lending money and charging interest was not uncommon (Millet 1991, p. 5). Therefore, Aristotle's view was not based on empirical but on ethical reasoning. Along with religious ideas, his writings were an important source of the ban on interest that delayed the development of NPV.

2.2 The ban on interest in Judaism

The philosophical refusal of interest also developed in most world religions (see the overview in Visser and MacIntosh 1998, p. 176). The Old Testament mentions the ban on interest rates several times. In Deuteronomy (Chapter 23), interest is banned for all money lending. In Exodus (Chapter 22) and Leviticus (Chapter 23), the ban is mainly on charging interest to the poor and disadvantaged. Although the passages in Exodus and Leviticus allow charging interest to non-Jews, the practice of charging interest in general was criticised on moral grounds. The Talmudic writings forbid charging interest as a reward for waiting for one's money (Lister 2006, p. 122). Overall, the Talmud is very critical of charging interest. The interpretation of the Talmud, however, allows Jewish merchants to charge interest if the terms and conditions of the interest are identical to those of other merchants charging interest.

The negative connotation of interest in Judaism (Wright 1998, p. 251) might also derive from the Hebrew word for interest, *neshekh*, literally meaning 'a bite'; it is believed to show the debtor's reaction to interest (see Wilson 1572/1925, p. 241; Visser and MacIntosh 1998, p. 177).

2.3 The ban on interest in Christianity and Islam

The origin of the ban on interest in Christianity lies in the Judaic tradition, which Aristotle's view – after the rediscovery of his writings in the 10th century (Bianchi 2007, p. 49) – reinforced. A passage in the New Testament extends the argument against usury: 'If you lend to those whom you expect to receive, what credit is that for you? Even sinners lend to sinners in order to receive back the same amount' (Luke 6:34). This led to an official ban on interest that was codified in the First Council of Nicaea in 325 AD. The ban was, at first, limited to the clergy and was increasingly broadened. During the time of Charlemagne, charging interest was prohibited for all people. In 1311, during the papacy of Clement V, usury was declared absolute and all secular legislation null and void (Menache 1998, p. 304).

During the scholasticism period of the Middle Ages, Thomas Aquinas elaborated on Aristotle's arguments (Geisst 2013, p. 19). Money was supposed to be sterile – the fruits of money were unnatural (Langholm 1984, p. 71). The exchange of real goods and products was only hiding behind the monetary processes that can be interpreted as a veil (Steuer 1936, p.74). Scholastic practice only allowed charging an interest rate if the loan was given in an emergency, if the creditor could not realise another profit because of extending the loan (in that case, the interest was limited to the lost profit) or if the repayment of the loan was overdue. Although the church still maintained the ban on interest, the lender's potential loss due to delayed or denied repayment was now accepted as a reason for interest – a major shift in the Catholic Church's point of view (Langholm 1998, p.74).

Although the Catholic Church only prosecuted usury in notorious cases, the usurer (the merchant charging interest) had to face two real risks. First, the debtor could take his loan case to the courts and, by doing so, attain a non-repayment of his loan. At the end of the 12th century, public denunciation of usury grew dramatically, fuelled by a speculative credit boom caused by the discovery of silver mines in Germany and elsewhere as well as the Christian expansion into Islamic Spain (Abraham and Mews 2007, p. 5). Second, usury was a mortal sin that was considered to lead

to eternal damnation after the Last Judgment. This was perceived to be a real threat in the Middle Ages.

Only in the early 19th century did the Catholic Church slowly renounce its ban on interest. In 1913, the *Catholic Encyclopaedia* acknowledged that even the Catholic Church charged interest on its own property (Vermeersch, 1913). The discourse in which interest was banned and regarded as a moral sin was the exact opposite of the theoretical and practical work on financial methodology that demanded interest rates. Only at the end of the 16th century did scholars begin, despite the strength of the moral condemnation, to engage in working with interest rates for purposes like project valuation.

The reformation did in principle not change the view on usury. The writings of Luther and his followers contain passages that still show a condemnation of charging interest (Kerridge, 2002). Only the reformer Johann Calvin (1509-1564) of Geneva had a more liberal view (Munro 2012, pp. 166). In 1540 the Habsburg Netherlands introduced a law that allowed an interest of up to 12 % on all commercial laws. The later Dutch Revolt which brought independence of the protestant Low Lands from catholic Spain was influenced by Calvinism. In 1545 Henry VIII of England introduced a bill that allowed a maximum interest of up to 10 % for all kinds of interest. He broke with the Catholic Church in 1536. Although this bill was soon revoked under Henry's successor it was restored under Elisabeth I in 1571 (Munro 2012, pp. 169). The protestant territories especially under the influence of Calvin changed to a more liberal attitude towards usury.

In the Muslim world, the charging of interest (*riba*) is prohibited until today (for the Islamic financial system, see Zaher and Hassan 2002). The prohibition in Islam is rooted in the idea that one cannot profit if one does not take any risks (Taylor and Evans 1987, p. 21).

3. The Problem of Compound Interest

Compound interest is necessary in order to include the time value of money in the calculation. One dollar today can be invested and earn money immediately. This effect is incorporated into NPV by using compound interest. Historically, compound interest was considered to be the worst kind of usury and was condemned in various medieval legal systems. The Quran explicitly prohibits compound interest (for a discussion of the ban on interest in Islam, see Chapra 2006, for historical aspects, see Ackerman 1981): 'O ye who believe! Devour not usury, doubling and quadrupling (the sum lent). Observe your duty to Allah, that ye may be successful' (Quran 3:130).

Compound interest was already charged in Mesopotamian times, when temples offered investments and credits (Neugebauer 1969). Interest on interest was calculated after the fifth year, when the credit had 'grown-up' (Kramer 1963, p.93). On the other hand, the Babylonian and Sumerian authorities proclaimed debt cancellations on a regular basis to reduce the burden of debtors, whose fortune could not rise in the same way as their debt with compound interest (Hudson 2000).

The mathematics of compound interest were elaborated upon during the 16th and 17th centuries and used in business life, e.g. in Italy (Smith 1953, p. 565). In 1566, Jean Trenchant published his book *L'Arithmetique* (the arithmetic) in Lyons; it included a chapter about compound interest. Trenchant addressed the issues in a mathematical manner without including practical examples (Lewin 1970, p. 128).

In 1613, Richard Witt published the book *Arithmetical Questions, Touching the Buying or Exchange of Annuities; Dealing for Present or Future Possessions; and Other Bargaines and Accounts, Wherein Allowance for Disbursing or Forebearance of Money is Intended; Briefly*

Resolved, by Means of Certain Breviats. Witt was '[a] practitioner in the Art of Numbers', as mentioned on the title sheet of the book (Lewin 1970, p. 121). This book demonstrated the concept of compound interest by using the formula $(1+i)^n$ and included tables showing an interest rate of 10%, which was the most widely used rate at this time. The book continues with practical advice about problems mostly relevant to merchants such as repaying debts, calculating annuities, etc. It can be concluded that, in 17th-century England, compound interest was common in merchants' daily business transactions; thus the concept had already been established in daily life. But the theoretical research and elaboration, which was a precondition for developing and refining investment rules, had not yet been undertaken. It was here that Leibniz wrote his decisive essay, discussed in Section 4 of this paper. Section 3 illustrates early contributions to NPV's evolution.

4. Early Contributions to NPV

While Greek philosophers refused interest, the Romans were more pragmatic and used interest in their transactions (Andreau 1999, p. 90). A problem that was already occurring in Roman times was the valuation of life annuities, which is similar to discounting future cash flows in an investment/valuation situation. Obviously, both the age and life expectancy of the beneficiary need to be considered in calculating the annuities. At the time, it was a common subject in court proceedings. Therefore, the Roman lawyer Ulpian (170–228 AD) developed a simple approach to value payments that was linked to life expectancy (see, e.g. Frier 1982). This calculation was needed, e.g. to value the life annuity for tax purposes and the legacy of the inheritance (since the life annuity could only have a maximum value of three quarters of the total heritage; Frier 1982). The present value of a payment depended on the current age of the beneficiary:

- If the beneficiary was 20 years or younger, the current value was equivalent to 30 annual payments.
- If the beneficiary was aged between 20 and 25 years old, the current value was equivalent to 28 annual payments.
- ...
- If the beneficiary was older than 60 years, the current value was equivalent to 5 annual payments.

This approach is similar to contemporary mortality tables, but the model lacks one important instrument: an interest rate is not charged, enabling payments at different points in time to be comparable. Ulpian's model does not consider the time value of money.

Although the ban on interest has its roots in the Bible, the aggressive fight against this sin started only in the 13th century when especially Italian banks expanded their business with loans and rentes (Munro 2003, pp. 502). Early medieval literature discussed the use of interest without ideological reservations. A prominent example is the *Liber Abaci* by *Leonardo of Pisa* called *Fibonacci* published in 1202. Although the book is best known for the Fibonacci sequence of numbers, it deals mainly with mathematical problems that have a commercial character (see Goetzmann 2004). Fibonacci uses the time value of money and the net present value method for valuing cash flows (Goetzmann 2004, pp. 26): A soldier receives a quarterly payment of 75. If this payment changes to a yearly payment of 300, a difference results due to the fact, that the soldier can earn every month a certain amount of interest. The annual payment results in a lower net present value than the quarterly instalments.

In 1582, the Dutch scientist Simon Stevin of Bruges published interest tables (*Tafelen van Interest*). The versatile Stevin, who engaged in philosophical but also practical discussions, e.g. in bookkeeping and military engineering, wanted to spread useful knowledge (ten Have 1956, p. 240)

and used know-how that bookkeepers already widely applied. He mentioned the formula for discounting cash flows in an appendix as a general rule for finding the most beneficial loan at a given interest (Schneider 1984, p. 334). Littleton and Yamey (1956) consider Stevin's contribution to be the first written document of NPV.

The problem of valuing life annuities has long been discussed. A breakthrough, paving the way toward modern calculation, came in the form of the book *Value of Life Annuities in Proportion to Redeemable Annuities* by Johan de Wit (1625–1672), which was published in 1671 (Rubinstein 2003, p. 47). He used an almost contemporary mortality table, stating that out of 768 nominees:

- Six will die every 6 months for the first 50 years,
- Four will die every 6 months for the next 10 years,
- Three will die every 6 months for the next 10 years and
- Two will die every six months for the next 7 years.

For every nominee, he calculated the present value of his annuity. De Wit assumed a compound interest rate of 4% in his calculation. He used compound interest by valuing a stream of payments, which is close to the NPV rule. The valuation of life annuities was elaborated further by Abraham de Moivre (1657-1754) and Edmund Halley (1656-1742). In his paper "Of Compound Interest" published in 1761 Halley developed a formula for the present value of an annual payment that starts in year 1 and ends in year T with a final payment (Rubinstein 2003). When x is the amount of the annual payment and r stands for 1 plus the interest rate for the annuity the formula reads as follows:

$$\left(\frac{x}{r-1}\right) \cdot \left(1 - \frac{1}{r^T}\right).$$

5. The Contribution of Gottfried Wilhelm Leibniz to the Development of NPV

5.1 'Meditatio Juridico Mathematica de Interusurio Simplicе' (Legal and mathematical discussions about simple interest)

Leibniz was born in Leipzig, Germany in 1646, a time when his country had been destroyed by the horrors of the Thirty Years' War, which explains his lifelong preoccupation with peace. His father was a university professor. He became the last man who was thought to have the complete knowledge of his time. His achievements ranged from developing a machine to measure wind velocity to inventing infinitesimal calculus (consisting of integral and differential calculus). The latter was developed independently by Newton.

His essay 'Meditatio Juridico Mathematica de Interusurio simplicе' was highly relevant to the development and implementation of NPV (Leibniz 1962, p. 125).

In his essay, several versions of which were written between 1680 and 1683, Leibniz begins with the definition of three principles he thinks everybody can agree upon in a situation where one person is the borrower and the other is the lender:

- (1) Everyone who pays back an amount of money earlier than contractually necessary can claim an adequate amount of interest for it.
- (2) Payments are not necessary. Offsetting receivables and payables are also allowed.
- (3) Both parties can always agree on earlier payments and/or offsetting.

Assume that the debtor repays on dollar today even though it is due in one year. The consequence of Principle 1 is that the creditor has to pay interest on this amount. Since offsetting is

allowed (Principle 2), the debtor can reduce the interest on his or her repayment. If we assume an interest rate of 5%, the debtor has to pay one dollar and five cents of interest. This interest is, however, due one year after the original payment period. As a consequence, the debtor has to pay interest on the interest he or she receives from the creditor. The numerical series can be continued as long as necessary. The logic Leibniz applies is nothing other than the NPV rule.

It is interesting to note that Leibniz changed his view about compound interest while writing the ‘Meditatio’. In the first version, he still concluded that compound interest was unacceptable (Leibniz 2000a, p. 69), which shows how deep the resistance to compound interest was rooted in the general thinking of his time. This is, in addition, reflected by the fact that he camouflaged his work with compound interest by using the term ‘simplice’ in the heading of his paper (von Bortkiewicz 1907, p. 73).

In the second version, he mentioned a formula equivalent to NPV that is still used today (Leibniz 2000b, p. 112):

$$a\left(\frac{v}{v+1}\right)^z,$$

where a is the amount of debt, z is the number of years for which the money is lent and $1/v$ is the interest rate. If the fraction is reduced by v and $1/v$ is written in modern notation with i , the modern NPV can be identified using the following formula:

$$a \cdot \frac{1}{(1+i)^z}.$$

In the ‘Meditatio’, the calculation with compound interest was not explicitly stipulated for loans, but it was explicitly stated for any other series of payments, such as annuities and investments. Leibniz makes the jump to project valuation that was up to this point hindered by the religious ban on interest.

Although Leibniz’s work is not the invention of NPV, it logically deduces it based on his three easy-to-accept principles. He drew the conclusion with mathematical and logical deductions; it contradicted the prevailing opinion and legal situation of the time. His critics argued that by using compound interest, his theory was disproved (see the overview in Schneider 1994, p. 335). Leibniz, however, postulated that the legal rules should follow the logical rules; thus, his logic was difficult to refute.

5.2 The reception of Leibniz’s work

Leibniz’s approach was very modern. By using compound interest, he implies that the money, which is repaid, is invested by the creditor at the interest rate, which is in turn paid by the debtor – a consequence visible in modern investment theory as an outcome of the complete market model.

Nevertheless, its implementation was slow. The first state to implement NPV was the Kingdom of Saxony; it adopted Leibniz’s method for public disputes in 1724, when debts were repaid ahead of time. In 1804, some counties of Prussia followed. Most of the German states continued to use the linear calculation without compound interest until 1829 (Löhmann 1829, p. 80).

Leibniz’s calculation was reflected in the most common mathematical textbooks in Germany: von Clausberg used the Leibniz formula for paying back debts in his book *Demonstrative Rechenkunst (The Demonstrative Art of Calculation)*, published in 1732 in Leipzig, Saxony (von Clausberg 1795, p. 1263). Von Clausberg, who was regarded as the best mathematician of his time (Cantor 1876, p. 285), promoted the Leibniz formula. His book became one of the most influential sources of calculation methods and was published in various editions after his death in 1751. De

Florencourt discussed the Leibniz formula in his book *Abhandlungen aus der Juristischen und Politischen Rechenkunst (Essays in the Art of Juridical and Political Calculation)*, which was published in 1781. The 1782 book *Anleitungen zur Juristischen, Politischen und Ökonomischen Rechenkunst (Instructions on the Art of Juridical, Political and Economic Calculation)* by Johann Andreas Michelsen was also positively received.

Leibniz's work was adopted in some parts of juridical literature as well. Because of its standing, the German jurist Anton Friedrich Justus Thibaut wrote in his book *Introduction to the Study of Jurisprudence* (published in German as *System des Pandektenrechts* in 1803): 'The only principle which is correct at least theoretical and in general, is that stated by Leibniz . . . with compound interest for the remaining time . . . There is here evidently no infringement of the law which prohibits the taking of compound interest' (Thibaut 1855, p. 164). Other scholars were still against using Leibniz's rule. *Rechtslexicon für Juristen Aller Teutscher Staaten*, published by Julius Weiske, dismissed the idea of using Leibniz's method on the grounds that he used compound interest. He favoured alternative calculation methods that used simple interest (Weiske 1844, p.641). This shows how deep the resistance to using compound interest and thus NPV was.

6. The Evolution of the Contemporary Use of NPV

These early discussions did not lead to a widespread use of NPV and its application in finance; also, the theoretical breakthrough did not lead to a practical breakthrough. Although the religious prohibitions related to the charging of interest for loans had been repealed, the aversion to interest was so deep that it was not used for, e.g. project valuation. Only in the beginning of the 19th century did the idea of valuing projects with NPV become relevant, as more and more authors advocated its use for the appraisal of investments. At the same time, the religious prohibitions were eased and the practice of merchandise instruments that used interest rates spread. NPV's evolution was influenced by three determinants of the time: political economy, engineering economics and academics as well as consultants who popularised the method after World War II.

6.1 The contribution of political economy

In his 1920 landmark book *Principles of Economics*, Alfred Marshall discussed the concept of discounting cash flows. He stressed that the revenue from an investment must exceed the original cost by an amount that considers the weighting time at compound interest (Marshall 1920, p. 352). He also mentions that for risks and potential delays, the investment must earn a surcharge. Moreover, Marshall mentions that changes in the purchasing power of money must be considered. Investments are carried out by an 'alert businessmen' as long as he thinks that the investment can compensate him for his outlay (Marshall 1920, p. 356).

The Austrian economist Böhm-Bawerk (1903) also describes the use of NPV. He analyses the problem of a house that is offered by a payment of 20 annual instalments of 1,000 currency units each. He claims that the decision should be made by considering the NPV of all 20 instalments (Böhm-Bawerk 1903, p. 36).

It is unclear who the first scholar to effectively popularise NPV as a rule for investment decisions was. One debated possibility (Poitras 2006, p. 122) is Irving Fisher's book *The Rate of Interest*, which was first published in 1907 and again issued after being revised as well as significantly extended in 1930 as *The Theory of Interest*. Fisher's contribution is a clear system for analysing the benefit of investments; he credited his work to the Scottish economist John Rae (1834). Fisher's book contains an important idea for the theoretical and practical spread of the NPV rule. He derived the separation theorem that bears his name. The Fisher separation theorem asserts

that it is sufficient that a company maximises net present value regardless of preferences of the company's shareholders (Rubinstein 2003).

6.2 Engineering economics

Fisher's predecessors, especially those coming from the engineering profession, wrote about discounting techniques to select profitable investments (e.g. Haka 2007, p. 704; Parker 1968 p. 61). This discipline used a lot of knowledge and sources from the German agricultural and forestry sciences (see Greulich 2002). Since the common textbooks in practical mathematics and legal studies in Germany used the Leibniz formula, an indirect connection can be assumed.

Wellington's (1877) work is prominent. Wellington was himself a locating engineer for railroad companies in the US (Dulman 1989, p. 558). Based on his practical experience, he concluded that the decision to build a railway line needed careful reasoning because of the massive capital expenditure required. Wellington published a table showing the present value of a unit of money being invested at a specific rate of return for a given number of years (Wellington 1877, p. 83). His table is similar to tables published in contemporary textbooks as guiding instruments for solving NPV exercises. In the second edition of his book, published in 1887, he significantly extended his coverage of NPV techniques (Wellington 1887). Compared to contemporary NPV, his concept still contains two flaws (Dulman 1989, p. 560): Firstly, he used the loan rate of the company as a discount rate, neglecting the cost of equity. Secondly, he ignored an adjustment for risk in the discount rate.

Another source of NPV in engineering economics is the textbook *Principles of Engineering Economy* by Stanford professor E. L. Grant (1950), which was first published in 1930. He mentioned that, especially when payments and revenues occur on different dates, interest has to be considered in order to make an appropriate appraisal. Grant was praised for his initial presentation of NPV in a textbook (Jones and Smith 1982, p. 105).

Engineers have long used discounted cash flows, but this idea had not been very influential before management thinkers popularised NPV (Shillinglaw 1980, p. 6). Nevertheless, according to Weaver (1954), it was oil and chemical companies with a strong background in the engineering profession who pioneered NPV as a management technique in the 1950s (p. 19). AT&T was an early adopter as well – Grant worked for the company and assisted them in developing tools for capital budgeting (Dulman 1989, p. 568).

6.3 Development after World War II

Johnson and Kaplan (1987) regard the adoption of the NPV rule as 'the main innovation in management accounting' of the last 60 years (p. 163). The breakthrough of this management technique began after World War II.

Probably the most influential author in popularising the idea of NPV was the economist and consultant Joel Dean (Scorgie 1965, p. 88); he published his book *Capital Budgeting* in 1951 and advocated the method via his consulting business (Haka 2007, p. 705). In his writings, he refers to 'discounting the stream of capital earnings to take account of the diminishing value of distant earnings'. In other articles, for example those found in the *Harvard Business Review* (Dean 1954), he criticises management decisions and strongly advocates for his consulting business (Scorgie 1965, p. 88). He mentioned that NPV had been used for years but had few applications in capital budgeting (Dean 1954, p. 129). NPV played a prominent role in the United Shoe Machinery Company antitrust case. The company held more than 90% of the market share in shoe machinery. The District Court of Massachusetts required the company to present a method for calculating a fair price for its machines. It worked – amongst others – with Dean's consulting company, which

formulated a pricing scheme based on the NPV rule. This case promoted the use of NPV in American business (Dulman 1989, p. 583).

Two other contributors that popularised NPV, as mentioned by Schneider (1984), are James Lorie and Leonard Savage (1995), with their paper ‘Three Problems in Rationing Capital’, published in the *Journal of Business*. Their paper discussed the problem of a company having several positive investment opportunities but only a limited amount of money with which to finance these investments.

NPV is currently a broadly accepted rule for valuing projects, appraising investments and specifying the value of companies. Bodie and Merton argue (2000, p. 113) that ‘none of the rules are as universally applicable as the NPV rule’. Still, in 1938, Ronald Coase, who received the Nobel Prize in 1991, championed using NPV techniques to make investment decisions in a series of articles (1938). The method was not used in common practice before the 1960s (Faulhaber and Baumol 1988, p. 584). Its increasing usage was accompanied by other management techniques that were more popular at the time. More sophisticated management tools evolved from the 1950s onward, since companies had to face more unpredictable environmental turbulence (Chawla, Mangaliso, Knipes and Gauthier 2012, p. 202). Empirical studies show that today, most companies use NPV (see, e.g. Pike 1996; Arnold and Hatzopoulos 2000; Graham and Harvey 2002).

Governmental bodies supported the use of NPV in investment appraisals, as they assumed that wrong investment decisions cause slow economic growth. Another reason for the late breakthrough was the introduction of computers, which made calculation much easier (Rutterford, 2004).

As shown, the development of NPV was slow; it needed the practical approach of consultants for its breakthrough, although the basic theory had already been developed in the 16th century.

7. Conclusion

Today, NPV is a key concept in finance and management; it is widely accepted in theory and practice. Other globally accepted principles had a much easier history. Double entry bookkeeping, for example, developed as the worldwide standard considerably earlier (see Lauwers and Willekens 1994). The reason is not a lack of theory or the sophistication of the concept of NPV; instead, the obstacle to this principle was the historic ban on interest, more specifically the ban on compound interest, found in most world religions.

Gottfried Wilhelm Leibniz, a German scholar, is responsible for the theoretical breakthrough of NPV. In his essay ‘Meditatio juridico-Mathematica de Interusurio simplice’, he developed NPV based on three easy-to-accept principles. In doing so, he utilised compound interest, which critics of usury considered to be even worse than simple interest. The Kingdom of Saxony adopted this theory, using Leibniz’s approach for valuing assets in public disputes. German juridical and mathematical literature followed suit. Concurrently in England, Witt’s writings used compound interest for practical issues in trade. Nevertheless, the resistance to the use of compound interest was so deep that the common use of this technique only commenced only in the 1960s.

After explaining the ban on interest as an obstacle to the development of NPV, this paper emphasised Leibniz’s role in its development; English language literature has only marginally recognised his achievements. With his original approach of deducting NPV from easy-to-accept principles, he certainly has his place in the history of investment theory.

Further research should investigate the investment appraisal methods that were used in ancient and medieval times. Furthermore, the effects of the ban on interest, especially compound interest, in the delay of developing further banking and management instruments should be studied.

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