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Consumer-led pension strategy – Workstream 2

Derivation of a social discount rate for assessing UK electricity consumer preferences for bearing DNO pension cost and risk

Western Power Distribution

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1.1 Background and context

Over the current decade the network companies face an unprecedented challenge of securing significant investment to maintain a reliable and secure network. As the regulator, Ofgem's role is to ensure that this investment is delivered at a fair price for consumers.

To help achieve this, Ofgem developed RIIO (Revenue = Incentives + Innovation + Outputs) – A performance based model for setting the network companies' price controls, which lasts for eight years. RIIO is designed to encourage network companies to:

- Put stakeholders at the heart of their decision making process;
- Invest efficiently to ensure continued safe and reliable services;
- Innovate to reduce network costs for current and future consumers; and
- Play a full role in delivering a low carbon economy and wider environmental objectives.

It is relatively early days in the new world of enhanced consumer consultation and to date a number of areas have been excluded from the consultation process by network operators. However, Ofgem have been explicit that pension costs (due to their complex nature and significant cost/risk to consumers) must now be included and the strategies adopted by network operators for running their pension schemes need to be in line with their consumer's views on efficiency.

Western Power Distribution ('WPD') instructed us in November 2015 to support them as they developed their approach to consulting with their consumers to determine the most efficient way to fund their pension schemes. The scope of our engagement included working with WPD to design and implement a methodology to seek consumers' views on how WPD should fund its pension schemes, using a combination of quantitative, qualitative and academic research based techniques. The engagement deadline was September 2016 in order to enable the results from the research to be implemented in the 2016 actuarial valuations of WPD's pension schemes.

During the early days of the engagement, Ofgem published a consultation on 16 March 2016 titled 'Second Consultation on Ofgem's policy for funding Network Operators' Pension Scheme Established Deficits.' This set-out the requirement for network operators to consult with consumers regarding their approach to funding their pension schemes. While the consultation document did not significantly alter the methodologies developed as part of our engagement, it did provide additional validation of the approach taken.

Some relevant excerpts from the consultation document are as follows:

1.6 We also outlined a marked shift from our current approach, that envisages penalties for NWOs that are outliers in the way their Pension Scheme Established Deficits are managed or valued, to **'a new approach that looks instead to NWOs to demonstrate how they are participating in the governance of pension schemes on behalf of the consumers' (who are underwriting the risks involved).**
We believe this approach more constructively recognises the substance of relationships between NWOs and pension scheme trustees who are ultimately responsible for the schemes. Respondents also broadly supported the direction of this thinking.

1.7 The aim of our proposed reforms is two-fold: (a) to underline Ofgem's commitment to consumer funding of Pension Scheme Established Deficits, which should help to minimise the cost of financing the networks themselves to the benefit of consumers, and **(b) to encourage NWOs to pursue consumer-focused strategies for managing their commitments.**

1.10 NWOs have responsibilities towards their consumers and the strength of the employer covenant is in part underpinned by our funding commitment on behalf of consumers. **This means we can reasonably look to NWOs to represent the interests of consumers when they participate in pension scheme governance**

In addition the consultation document included two specific amendments to Ofgem's policy for funding network operators' pension costs (called the pension principles) as follows:

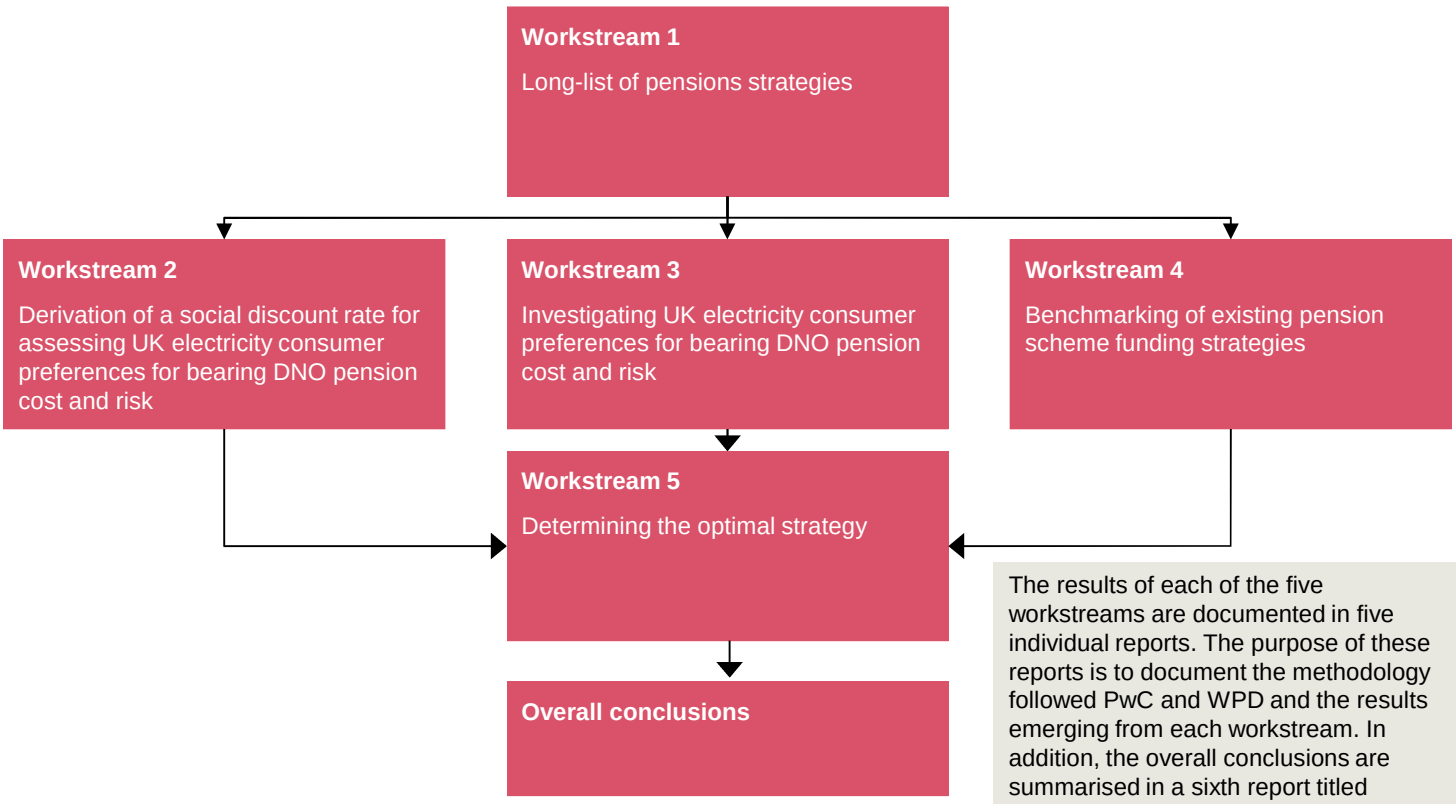
1 Consumers should not be expected to pay any excess costs that are avoidable by efficient management action

8 In light of our funding commitment, we look to employers to participate in the governance of defined benefit pension schemes with the aim of protecting the interests of the consumers who are exposed to any Established Deficit, in balance with the interest of shareholders who would be underwriting any remaining deficit. **To this end, we would look to employers to inform investment, benefit and funding strategies with objective and where possible evidence-based insights into the interests of consumers, recognising that tomorrow's consumers are as relevant as today's.** We look to employers to report transparently on their participation in the governance of these schemes.

1.2 Overview of the methodology

The methodology adopted by PwC and WPD comprised of five workstreams as follows:

Workstream	Purpose
1. Long-list of pensions strategies	• To identify the long-list of pensions strategies which could be adopted by WPD and determine their cost and risk profile for consumers.
2. Derivation of a social discount rate for assessing UK electricity consumer preferences for bearing DNO pension cost and risk	• To determine a discount rate using the academic research carried out to date for the purpose of comparing the relative cost (from a consumer and society perspective) of each of the pension strategies identified in Workstream 1 .
3. Investigating UK electricity consumer preferences for bearing DNO pension cost and risk	• Use primary research techniques to: - Validate and inform an amendment to the social discount rate determined in Workstream 2. - Determine other relevant factors for the purpose of assessing consumers' preferred pension strategy in Workstream 1.
4. Benchmarking of existing pension scheme funding strategies	• To provide relevant UK benchmarks for the funding of defined benefit pension schemes to provide additional validation that consumers' preferences are capable of practical implementation.
5. Determining the optimal strategy	• To assess the long-list of pension strategies using the results of Workstreams 2, 3 and 4 in order to arrive at a pensions strategy arrived at using evidence based insights into the interests of consumers recognising that tomorrow's consumers are as relevant as today's.



The results of each of the five workstreams are documented in five individual reports. The purpose of these reports is to document the methodology followed PwC and WPD and the results emerging from each workstream. In addition, the overall conclusions are summarised in a sixth report titled "Overall conclusions."

1.3 Purpose of this report

The purpose of this report is to estimate a social discount rate which will be used to assess the overall cost from a consumer and society perspective of each of the pension strategies identified in the report titled 'Long-list of pensions strategies.'

This requires going beyond conventional individual or corporate discount rates and assessing social discount rates, which can be used across multiple generations of electricity consumers.

This report draws heavily on the academic literature in this area, and other policy decisions which have required talking a long-term perspective on intergenerational consumer preferences. These findings are then validated by bespoke primary research which is documented in the report 'Investigating UK electricity consumer preferences for bearing DNO pension cost and risk'. This enables testing of consumer preferences in relation to the cost and profile of the pension cost element of electricity bills. By combining these two techniques, this report benefits from the rigor of academic study and the relevance of consumer insight testing.

The results of the analysis set-out in this report are then used in the assessment of the long-list of pensions strategies in the report titled 'Determining the optimal strategy'.

1.4 Structure of this report

Chapter 2 defines discount rates and the method used to discount pension costs. This chapter sets out the common components of a discount rate and illustrates the application of discount rates to a cost profile to enable comparisons of different cost profiles.

Chapter 3 considers different methodologies used to estimate a risk-less discount rate and provides a review of discount rates obtained from academic papers and research reports. This chapter also assesses the results from the conjoint analysis carried out in the primary research (see accompanying report titled 'Investigating UK electricity consumer preferences for bearing DNO pension cost and risk') relating to time discounting and intergenerational discounting. The chapter concludes with suggestions for an appropriate risk-less social discount rate for WPD.

Chapter 4 incorporates the results from the economic first principles and conjoint analysis in order to adjust for risk. This section helps to bring together a risk-less social discount rate and risk premiums to give a risk-adjusted social discount rate for a range of different pensions strategies.

2. How to discount contributions payable to defined benefit pension schemes

2.1 Application of discount rates

A discount rate is used to convert future values to their present value. The requirement for discounting is driven by the observation that present consumption is typically valued more than future consumption. A discount rate renders benefits and costs that occur in different periods comparable by representing them in present value terms, and hence allows a like-for-like comparison of different costs, or between benefits and costs across different time periods.

The net present value ('NPV') of any investment plan or project is therefore influenced by the discount rate chosen. The size of the discount rate makes a significant difference to investment decisions where benefits occur in the future. Individuals with higher discount rates place smaller value on long-term benefits and therefore prefer projects with benefits that accrue early. Conversely, individuals with lower discount rates place greater values on longer-term benefits and will prefer projects with long-term term and more substantial benefits.

Table 1 illustrates the impact of changing the discount rate assumption for a hypothetical investment which involves a cost of £100 today (input) and generates a benefit of £200 in three years from today.

Table 1 Example of a traditional net present value application

	Year 0	Year 1	Year 2	Year 3	Option A: NPV 0% discount rate	Option B: NPV 5% discount rate	Option C: NPV 10% discount rate
Costs	£100	0	0	0	£100 (£200 – £100)	£72.8 (£172.8 – £100)	£50.3 (£150.3 – £100)
Benefits	0	0	0	£200			

From the above example, discounting future values by 5% per year suggests the benefits of £200 in three years would be worth £172.8 in present value terms. This means the net present value created by paying £100 today is roughly £72. However, using a 10% discount rate will reduce the present value of benefits to approximately £150. This example illustrates that the higher the discount rate, the higher the time preference for immediate benefits and the lower the value placed on future benefits.

Most traditional NPV analysis focuses on discounting a stream of future benefits and comparing to an investment cost. However, a similar discounting analysis can be used to compare two streams of future costs, in this case electricity bills.

A higher discount rate means that individuals will choose lower costs today and higher costs in the future compared to higher costs today and lower costs in the future in the case of a lower discount rate. This is because future costs will be more heavily discounted relative to costs incurred in the present.

Electricity bills are household costs and in the case of WPD, an increase or decrease in the electricity bill arises from a change in its pension contributions. The example below compares two separate electricity bill profiles.

Table 2 Example of applying discount rates to bill profiles

	Year 0	Year 1	Year 2	Year 3	Option A: PV 0% discount rate	Option B: PV 5% discount rate	Option C: PV 10% discount rate
Profile (1)	£100	£100	£100	£100	£400	£355	£317
Profile (2)	£75	£75	£125	£130	£405	£354	£313

Table 2 illustrates that the higher the discount rate, the higher the time preference for lower costs in the present. A preference for lower cost in the present can be interpreted as an unwillingness to increase the cost of electricity bills today (in order to achieve lower bills in future). The higher discount rate means that these individuals place a larger importance or weight on current consumption. Table 2 also shows how different discount rates can result in different preferred bill profiles: Option A for individuals with a 0% discount rates and Option B and C for individuals with a 5% and 10% discount rate.

These two examples show how the same discount rates can be used to discount benefits (in the case of projects requiring investment) or discounting a sequence of costs (in the case of pension costs) into a single present value for comparison purposes. However, the implications can be markedly different. Whereas low discount rates increase the present value of future benefits (and therefore increase the likelihood that an investment is economically worthwhile), low discount rates also increase the present value of future costs. In the case of comparing costs, consumers are typically seeking to minimise costs, so low discount rates can lead to higher cost outcomes in present value terms.

2.2 Types of discount rates

Individual discount rate

Individuals typically prefer to consume a given amount of goods and services sooner rather than later, because of the risk of not being alive in the future and the generally lower value attached to future consumption with respect to current consumption. The rate at which individuals would exchange a unit of consumption today for a unit of consumption tomorrow is represented by the individual discount rate.

Academic studies have identified age, income, health and mortality risk as some of the factors that have an impact on individual discount rates. In Appendix A we provide a review of the academic literature on the drivers of individual discount rates.

Some studies suggest a positive relationship between age and discount rates. This means that older individuals have a higher discount rate (which is attributed to lower remaining life expectancy). However, not all studies are consistent with this finding, particularly in earlier life. Most academic studies on income and discount rates suggest that poor individuals often exhibit higher discount rates. Additionally, negative income shocks and low levels of income have been linked to increases in discount rates.

Corporate discount rate

The corporate discount rate is the discount rate which compensates companies (and their investors) for foregoing current cash flows in order to achieve future cash flows, and companies use it to set target returns, assess performance and quantify value. One of the most common ways to compute this corporate discount rate is by estimating a firm's opportunity cost of capital (or weighted average cost of capital commonly known as 'WACC'). This approach proportionately weighs each type of capital (e.g. common stock, preferred stock, bonds, and other forms of long-term debt) in a company.

Assuming that a company has only two main sources of financing – debt and equity – the WACC is calculated by combining the returns on debt and equity with appropriate weights. The weight for the cost of debt is the gearing, i.e. the proportion of the total value of the company, which is financed with debt. The proportion of the total value, which is financed with equity, is the weight for cost of equity. The WACC is usually calculated using the following formula:

$$\text{WACC} = \frac{D}{D+E} * Kd * (1 - Tc) + \frac{E}{D+E} * Ke$$

where

- D is the market value of the firm's debt;
- E is the market value of the firm's equity;
- Kd is the cost of debt;
- Tc is the corporate tax rate;
- Ke is the cost of equity.

Social discount rate

The social or societal discount rate applies to a society as a whole. It therefore reflects all the individual discount rates across society. However, it also captures society's preferences for consumption of benefits obtained by future generations when used to discount long-term costs and benefits. Public decision makers use the social discount rate to discount benefits that are enjoyed by future generations, but paid for by the current generation.

Social discount rates are usually lower than individual discount rates as individuals are mostly concerned with their own welfare in the short-term. In contrast, when society is measured as a whole, these short-term and risk averse considerations are less important and a longer-term perspectives can be used, which typically values longer-term benefits more highly and therefore involves using a lower discount rate.

2.3 Components of a discount rate

There are four components of a discount rate, which are typically applicable to any type of discount rate (individual, corporate or social). These are explained below.

Inflation

Inflation is the increase in the price level of goods and services over time. With inflation and a certain nominal amount of money, individuals can buy fewer goods and services than they could previously. Therefore, even purely because of inflation and the fact that money devalues over time, for any monetary value that is given up in the present, individuals will want a compensation of more than that monetary value in the future. Discount rates therefore include an allowance for inflation.

An alternative approach to take account of the impact of inflation is to assess cash flows in real terms. This removes the impact of inflation from cash flows and requires the use of real-adjusted discount rates, which do not include an inflation component.

The rest of this report assess real discount rates. The discount rates derived therefore must be applied to benefits and costs expressed in real terms.

Pure time preference

Because of consumers' myopia and the risk of not being alive in the future, individuals prefer to consume goods and services now rather than in the future.

Even if inflation were zero and income was kept constant, the majority of individuals would still prefer an immediate reward to a future one because of a general impatience that characterises human preferences. This is called pure time preference.

While individuals demonstrate a distinct pure time preference, firms should have a lower time preference. This is because preferring to increase cash flows in the short-term (at a sacrifice of longer-term gains) for a company might not be a profit maximising decision for shareholders. Ultimately firms' shareholders are made up of individuals who do have pure time preference, but they are able to liquidate their investment by selling to other shareholders, if they require/value the benefits of investment in the short term. The market value of these firms will therefore be determined by those investors with longer term investment horizons, thereby reducing pure time preference which should be reflected in businesses decisions.

From a societal point of view, it is arguable whether policy makers should give higher weight to current generations compared to future ones. This means there may not be any pure time preference within a social discount rate, although there are a number of situations where this could happen – e.g. where political choices are biased towards the present circumstances rather than the future.

Opportunity cost

Individuals typically expect their level of consumption to increase in the future and marginal utility of consumption to diminish as a consequence. Given that an additional unit of consumption today provides more utility than an additional unit of consumption tomorrow, individuals would have to consume more than one unit in the future to compensate for sacrificing (saving) one unit of consumption now. This opportunity cost is greatest for those individuals with high expected growth in consumption, and lower for those individuals with lower expected growth (or decline) in consumption.

From the perspective of a company (or its investors), capital is productive and resources acquired for a particular project can be invested elsewhere. These resources therefore have an opportunity cost. Therefore, to invest in a project, the expected return from the investment should be at least as high as the opportunity cost of financing the project, which is represented by the expected return from the next best alternative investment. Therefore, for a typical project, the rate the investor should use in discounting benefits and costs is the marginal rate of return on investment in the private sector.

From a society perspective, there is also an opportunity cost of capital, also termed the marginal social opportunity cost of capital ('SOC'). Rather than considering alternative private sector investment opportunities, this considers alternative wider social opportunities.

Combining pure time preference and the opportunity cost of capital

Combining the pure time preference and the opportunity cost of capital concepts, Zhuang, Liang and De Guzman (2007) suggest that the rate to discount future benefits and costs should be the marginal social rate of time preference ('SRTP'), that is, the rate at which society is willing to postpone a marginal unit of current consumption in exchange for more future society consumption.

2.3 Components of a discount rate (Cont'd)

The SRTP is usually computed using the Ramsey formula, according to which SRTP is the sum of two terms:

- ρ, the utility discount rate reflecting the pure time preference
- the product of two parameters—the elasticity of the marginal utility of consumption (θ) and the annual rate of growth of per capita real consumption (g). This term of the formula reflects the fact that, when consumption is expected to grow in the future, people will be less willing to save in the current period to obtain more in the future, because of diminishing marginal utility of consumption.

With estimates of ρ, θ, and g, the SRTP using the Ramsey formula is:

$$r = \rho + \theta g$$

This means that society chooses consumption levels which equate the rate of return on savings to the rate of pure time preference plus the rate of decrease of the marginal utility of consumption due to growing per capita consumption.

Risk

Risk-averse individuals assign lower values to benefits that have more risk associated with them than to otherwise similar benefits that are less risky. The most common way of adjusting for risk is to compute a value that is risk adjusted.

The adjustment for risk depend upon the ability and willingness of the individual to bear risk. This will be driven by risk preference and how well the individual can diversify the risk, through holding other investments and assets. For a company with diversified shareholders, this means investors only require compensation for risks which add to investors overall portfolio risk. From the broadest society perspective, many risks can be diversified, or eliminated. This means that risk premia in social discount rates tend to be lower than those in both individual and corporate discount rates.

The following paragraphs describe the different methods for adjusting for risk in turn, following Damodaran (2008).

Risk adjusted discount rates

The most common approach for adjusting for risk in discounted cash flows is using a risk adjusted discount rate approach. When discounting expected cash flows for riskier assets, a premium is added to the risk free rate, in order to incorporate the higher level of risk.

Certainty equivalent cash flows

Alternatively cash flows can be adjusted for risk. ore risk averse investors would settle for lower certainty equivalents for a given set of uncertain cash flows than less risk averse investors and a similar result to the adjusted discount rate valuation approach can be achieved.

Post valuation risk adjustment

Another approach to assessing risk is to value a risky investment or asset as if it had no risk and to then adjust the value for risk after the valuation. The more common practice with post-valuation adjustments is for analysts to capture some of the risks that they can perceive in a risk adjusted discount rate and deal with other risks in the post-valuation phase as discounts or premiums. Thus, an analyst valuing a private company will first value it using a high discount rate to reflect its business risk, but then apply a discount to the computed value to arrive at the final value estimate.

Although the belief on the part of analysts that conventional risk and return models do not fully capture what they see as significant risks, there are clearly significant drawbacks with this approach. Both downside and upside risks can be easily double counted, if analysts incorporate their risk assessments into the both estimation of discount rates and cash flows.

Relative valuation approaches

Most valuations, in practice, are based upon relative valuation, i.e., the values of most assets are estimated by looking at the market prices of similar or comparable assets, standardised by using a common valuation ratios (price as price-earnings ratios).

The risk adjustments in relative valuation approaches often do not match up to the risk adjustments used in discounted cash flow valuations. The fact that risk is usually considered explicitly in discounted cash flow analyses gives them an advantage over relative valuations, with its ad-hoc treatment of risk. However, the nature of the risk adjustment in discounted cash flow valuation makes it more time and information intensive

3. Estimating a (risk-less) discount rate for appraising bill profiles

3. Estimating a (risk-less) discount rate for appraising bill profiles

This chapter estimates a discount rate for the purpose of appraising different bill profiles for WPD's consumers. Risk is not incorporated into this estimation; it is instead included in chapter 4. The estimation requires specification of whether to use an individual discount rate, or a social discount rate, or blend of the two. This is largely driven by the time period of bill profiles being considered. Short term consumer bill trade-offs are best appraised using individual discount rates, but longer-term bill trade-offs are best appraised using social discount rates.

The demographic profile of electricity bill payers changes due to mortality, immigration and emigration from the regional distribution services area. In Appendix C the impact of these factors on the population of WPD bill payers is assessed. The findings show that with the combined influence of aging consumers and both international and regional emigration, only half of WPD's current consumers are expected to still be WPD consumers after 16 years. This means that any decisions, which influence long-term costs (such as pensions) quickly require the use of social discount rates.

This chapter introduces three approaches that will inform our estimate for the social discount rate:

- The first approach uses economic first principles, where a fundamental macroeconomic view is taken in estimating a social discount rate.
- The second approach is a benchmarking exercise that gathers some of the social discount rate estimates previously used and proposed by policymakers. Some of these estimates have been updated to reflect the low cost borrowing environment of today and have been made relevant for the current market situations.
- The third approach uses primary research. It involves a conjoint analysis, where responses from survey respondents reveal information about their individual discount rates and their intergenerational preferences. The conjoint analysis is most relevant for the purpose of estimating a social discount rate, as it enables observation of the impact of different electricity bill profiles on consumer choices

3.1 Estimating a discount rate using economic first principles

The social rate of time preference depends broadly on the pure time preference and the growth rate of per capital income. Studies discussed in Section 2 and Appendix A suggest that pure time preference is positive when it reflects individuals' choices. However, from a corporate or societal perspective is assessed, there is less of a case for a pure time preference rate.

The growth rate of per capital income is in the range of 1.5–2%[1]. This range is also close to the historic average of real risk free rates. This is no surprise as the Ramsey-Caas-Koopmans' model demonstrated a link between risk-free rates and long-term GDP growth of the economy – in equilibrium.

Current risk-free rates are highly impacted by loose monetary policy, so the long-term growth rate of the economy serves as a more stable indicator of social discount rates, and especially in this case as the discounting occurs over a long period of 50-60 years.

[1] The Green Book (2003) used an estimate of 2.1% for the opportunity cost of consumption. However this was a pre-crisis estimate and since then economists have revised likely long-term GDP growth per capita to reflect the effect of the 2008 crisis that has resulted in lower economic growth

3.2 Estimating a discount rate using existing benchmarks

Table 3 sets out a range of social discount rates or social rates of time preference used for the evaluation of long-term policy decisions.

Table 3 Review of social discount rate estimates

Type of discount rate	Estimate	Comments
Treasury Test Discount Rate (TDR), suggested by the H.M. Treasury based on the Green Book	3.5%	The Green Book recommends that costs and benefits occurring in the first 30 years of a programme, project or policy be discounted at an annual rate of 3.5%, and recommends a schedule of declining discount rates thereafter.
Marginal social opportunity cost of capital (it is expected return from the next best investment alternative)	5.5%	According to Zhuang, Liang, Lin, De Guzman (2007) the marginal social opportunity cost of capital could be approximated by the marginal pre-tax rate of return. The estimate used for the purpose of this report reflects the real yield of the IBOXX index on European Non Financial Corporates 15+ in 2007
Adjusting intergenerational equity-adjusted present values with distributional weights	Distributional weights: 1.6 over one generation 2.2 over two generations	Scarborough and Bennett (2008) in a choice experiment found that, over two generations, the community has positive preferences towards future generations. The fact that both distributional weights estimates are higher than one implies lower discounting on projects that affect future generations.
Social Time Preference rate (it is the rate at which society is willing to postpone a marginal unit of current consumption in exchange for more future consumption)	1.4%	The Stern Report (2007) used 1.4% real to discount the benefits from greenhouse gas emissions abatement policies.
Social discount rate	1.35–2.65%	Gaurnat (2008) estimated the range of social discount rate from climate change benefits to lie between 1.35 and 2.65%.

The Green Book (2003) uses the SRTP method and recommends a real discount rate of 3.5% for benefits and costs occurring thirty or fewer years in the future. This rate declines to 3% for benefits and costs occurring post thirty years and to 2% for 350 years in the future. In 2003, the real risk free rate in the UK was approximately 2.5% and the guidance suggested adding a justifiable 1% risk premium to compensate for public investment projects equated to the overall 3.5% rate suggested by the Treasury.

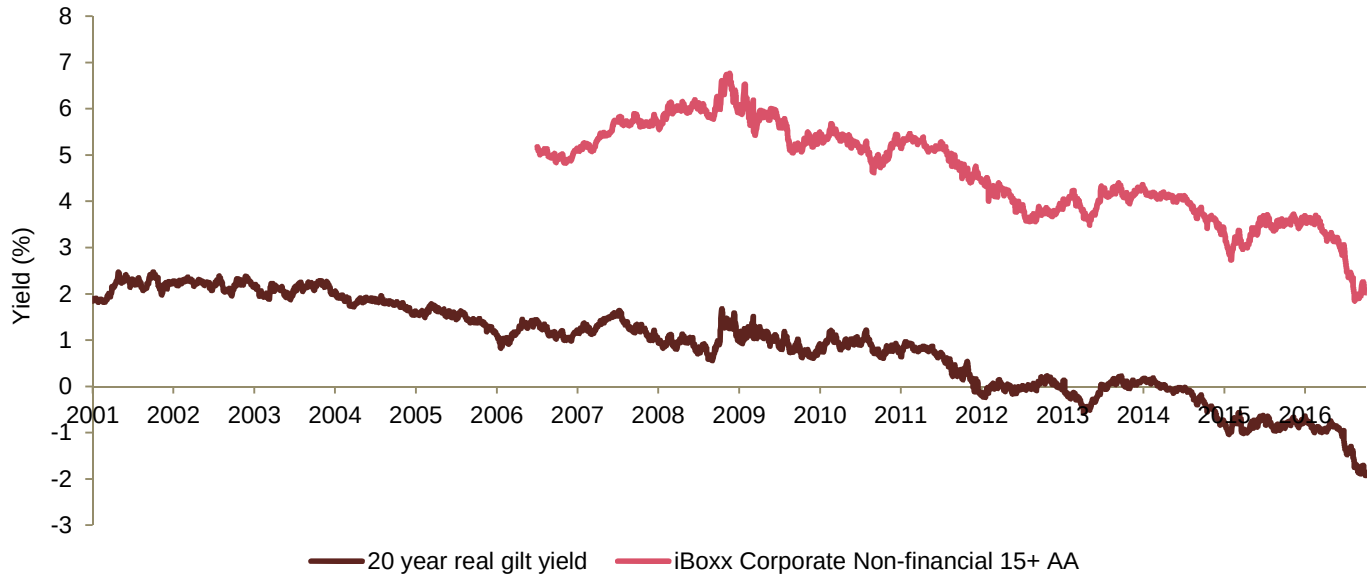
However, since 2003, there have been significant changes in the financial markets and global economic performance that has driven UK gilt yields down, to such an extent that it breached the 0% real risk free rate boundary in 2011.

Against a completely different economic backdrop compared to 2003, the 3.5% social discount rate may not be justifiable based solely on the real risk-free rate and the 1% risk premium. Adjusting the green book 3.5% figure for movements in interest rates suggests a figure of 1.15% (using a trailing average approach).

The risk premium is also considered separately in subsequent sections.

3.2 Estimating a discount rate using existing benchmarks (Cont'd)

Figure 1 UK real risk free rate and iBoxx corporate bond index



Source: Bank of England, Datastream

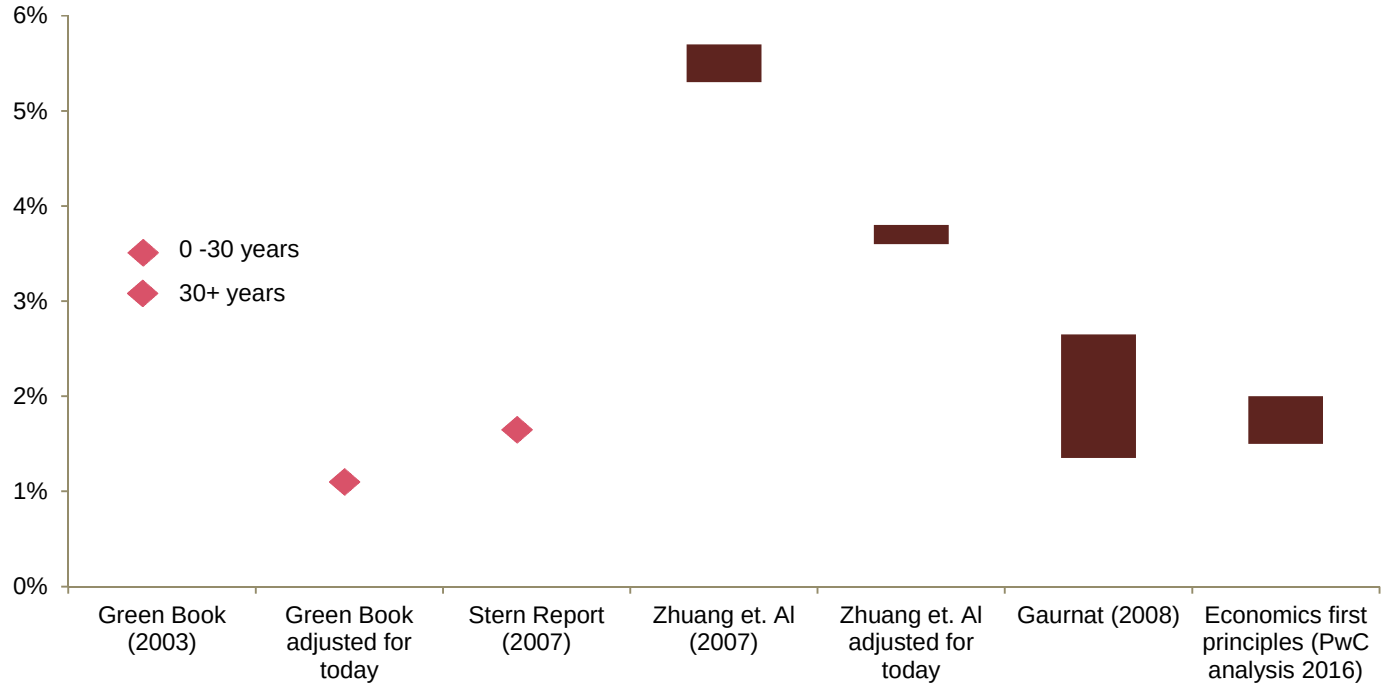
By contrast, Zhuang et. al (2007) estimates the social discount rate using the marginal social opportunity cost of capital. They share the view that since capital funds are limited, any capital invested in a project for public benefit (in this case WPD's pension scheme), will displace other projects in the economy. Therefore, the economic appraisal of pension contributions should be one that uses a discount rate that reflects the opportunity cost of capital. Generally, the capital displacement for WPD would be some form of private investment in the electricity sector. They consider that the marginal pre-tax rate of returns (the real yield on corporate bonds) could serve as a proxy of the marginal social opportunity cost of capital. Irrespective of the choice of methodology used by the Green Book and Zhuang et. al (2007), there is a need to revise their estimates as both studies were published before the global financial crisis and the significant reductions in interest rates which followed.

The estimate of the marginal pre-tax return for the purpose of this report is the real yield on the iBoxx index for European Non-financial corporates with more than 15 years to maturity. As shown in Figure 2, there has been a downward trend in the yield on corporate bonds over recent years. The high demand for government bonds and to some extent corporate bonds has pushed yields down. Current real iBoxx yields are around 2.0%.

The Stern Report (2007) gained attention in supporting the abatement of greenhouse gas emissions by 3 percent per year (relative to the baseline, which was business as usual). In order to support this policy, the report suggested using a social discount rate of 1.4%, which at the time of the review was lower than that used by other economic studies such as the 3.5% of Green Book estimate. The Stern Report argued that all social discount rate choices should address only ethical considerations and should not be based on expected interest rates or the marginal opportunity cost of capital. In contrary, studies like Zhuang et. Al and Nordhaus maintain that it is imperative to incorporate any market observations in the discount rate to ensure it is empirically sound and robust. Figure 3 presents a summary of these single social discount rates.

3.2 Estimating a discount rate using existing benchmarks (Cont'd)

Figure 2 Summary of benchmarking of social discount rates



Source: PwC analysis

The range of results from studies that use different methodologies suggests there is range for the appropriate social discount rate. The most popular methodology in literature prefers using observed market behavior and ideally would require an assessment both at a macroeconomic level (analysing long term GDP growth rates, risk free rates, and corporate bonds) and a microeconomic level (identifying consumer time preferences and risk appetite) to form an overall opinion on the social discount rate.

3.3 Estimating a discount rate using primary research

Analysis was carried out to estimate the social discount rate using primary consumer research. Full details of the methodology and results are set-out below.

3.3.1 Statistical technique used – conjoint analysis

Conjoint is a statistical preference technique which is well established in market research and academic studies. It works by decomposing a product or service into its main value attributes and asking individuals to make trade-offs between products or services to understand the value of their underlying attributes.

Conjoint analysis can be used to determine two main elements of the risk-less discount rate:

- **Time preference:** The trade-off between paying lower electricity bills today and higher electricity bills in the future. The responses provided information about each survey respondent's time preference in relation to bill payments.
- **Intergenerational transfer:** The choice between two types of electricity bill profiles, both characterised by higher bill payments today and lower bills for future generations.

3.3.2 Summary of research

The research was carried during April 2016 and included responses from 1,006 domestic electricity consumers, 1,005 business electricity consumers.

For more detail on the specific questions and profile of the respondents, see the report titled 'Investigating UK electricity consumer preferences for bearing DNO pension cost and risk.'

3.3.3 Methodology

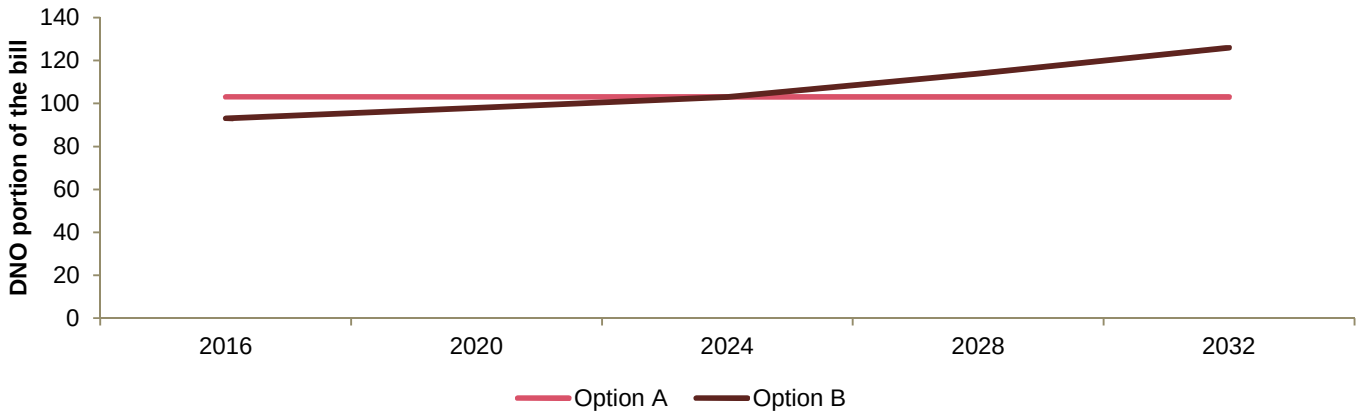
Time Preference

The first type of conjoint question addressed the time preference of individuals when faced with two randomly generated electricity bill profiles. An example of the two profiles is shown below:

'Thinking about the portion of your annual electricity bill relating to the cost of your Distribution Network Operator (DNO) both now and in the future, which of the following bill profile options would you prefer

Table 4 Conjoint style options on time preference of bills

	2016	2020	2024	2028	2032
Option A	£103	£103	£103	£103	£103
Option B	£93	£98	£103	£114	£126



Source: PwC analysis

Respondents had to make a choice between the static bill profile and a gradually increasing bill where respondents face lower bills until 2024 and higher bills after 2024. After collecting all the responses on the time discounting trade-offs, the discount rate that equated the net present value of the two electricity bill profiles was calculated.

In the example provided in Table 4, if the survey participant had chosen Option A (static bill profile), he/she would have a pure time discount rate higher than the one that equals the Net Present Value of Option A and Option B. On the contrary, the individual would have a lower discount rate had he/she chosen Option B.

A similar exercise was conducted for each of these sets of questions answered by the respondents and from this an estimate of the discount rates observed across the sample of respondents was calculated.

3.3 Estimating a discount rate using primary research (Cont'd)

Intergenerational preference

The second type of conjoint question adds a social dimension to the individual discount rates assessed above. This line of questioning provides an insight into the intergenerational preferences of the current electricity bill payers, i.e. if individuals today were willing to increase their electricity bill costs today to reduce electricity prices that future generations might face. Specifically, the respondents were asked the following question:

'Imagine that the portion of your annual electricity bill relating to your Distribution Network Operator's (DNO) costs is £100 in 2016. By 2046, the average DNO portion of the bill would be expected rise to £175 in line with rising living standards but instead rises to £250 as a consequence of rises in electricity specific costs.

Thinking about how much you pay towards the cost of a DNO now and the amount your kids or next inhabitants of your household (i.e. bill payers in 2046) will pay, to what extent are you able to share the increase in electricity costs with the future generation?'

Table 5 Conjoint style options on intergenerational preference of bills

Option A	The increase in electricity bills (for the DNO costs) in 2016 will be £15 per year and the price future generations will pay in 2046 will reduce by £31.
Option B	The increase in electricity bills (for the DNO costs) in 2016 will be £20 per year and the price future generations will pay in 2046 will reduce by £44.
Option C	Not willing to accept an increase in bill in 2016 to reduce the bill for future generations in 2046.

In the survey, each individual was shown three different questions for the three types outlined above. Compiling all the responses from all the respondents enabled the running of statistical analysis to understand the trade-offs that individuals made between benefits and costs. It was then possible to estimate an individual's discount rate from their preferences on time, risk/volatility and intergenerational altruism.

In the survey, the conjoint questions were supplemented with qualitative questions on willingness to pay in order to validate the results of the conjoint analysis.

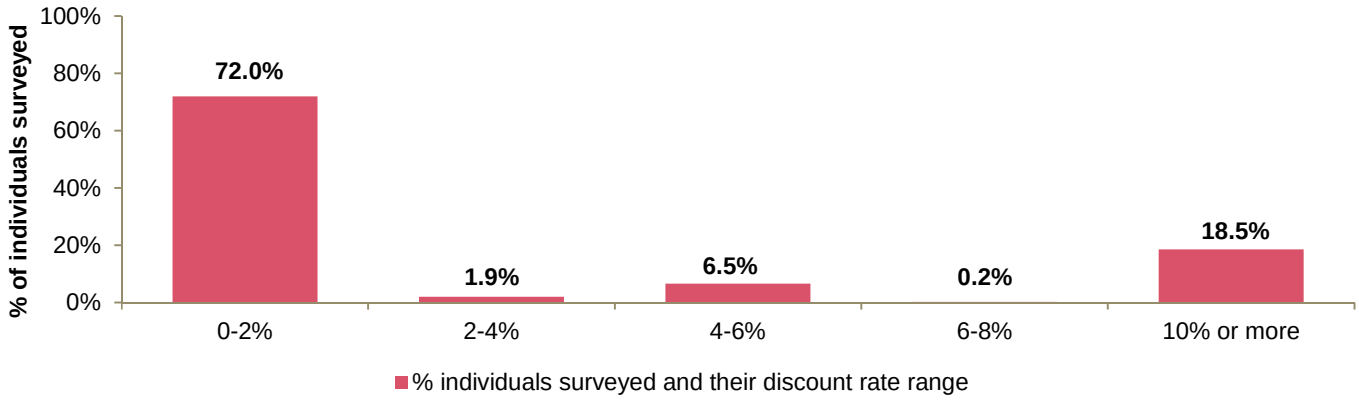
3.3.4 Results

Time Preference

The choices on the trade-offs between levels of current and future bills provided a range for each individual's time discounting preferences. The results of these ranges are shown in Figure 4 below.

The output is a distribution of individuals who lie below or above different time discount rate ranges, however it does not provide their discount rate point estimate. The results indicate that more than 70% of respondents made bill profile choices that reflected a discount rate between 0-2%. This means that a significant part of the sample had a low discount rate. A low discount rate implies that individuals do not prefer significantly higher bills in the future if faced with lower bills today. They would rather face a relatively static bill profile, which also shows a general bias towards flat bills.

Figure 3 Range of time discount rates for respondents



Source: PwC analysis

3.3 Estimating a discount rate using primary research (Cont'd)

The weighted average time discount rate was calculated using the mid-point of each range and weighting it by the frequency of individuals who lie within that range.

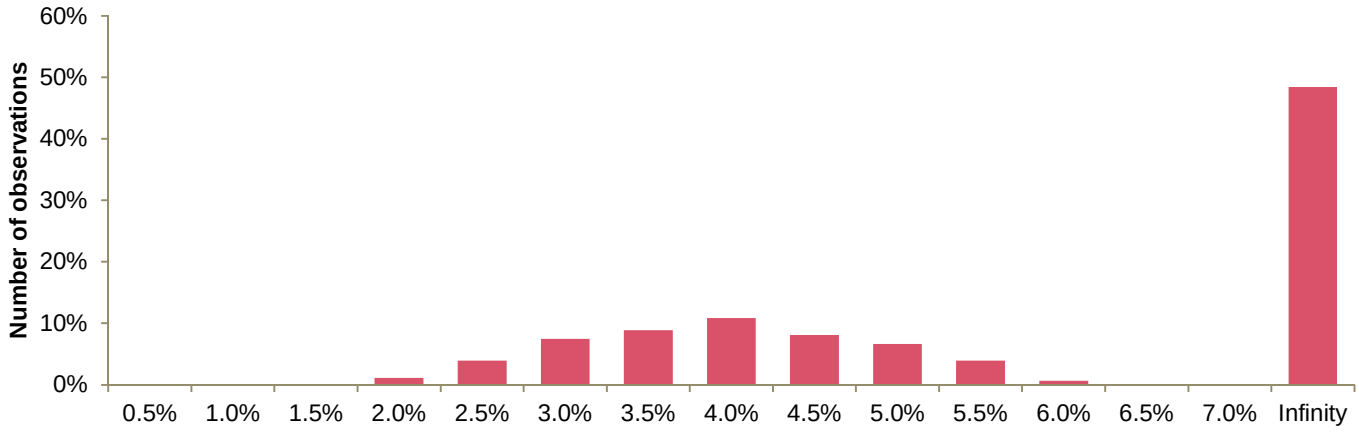
The weighted average time discount rate was calculated as **2.8%.**

Intergenerational preference

Future generations could be faced with uncertainties in the electricity markets that might drive electricity bills up, possibly due to some of the actions made by individuals today. With this backdrop, individual respondents were asked to choose between two options where they were willing to bear an increase in their current bill to reduce the bills of future generations, or state a preference where they weren't willing to increase their costs today for any amount of benefits for future generations.

Their choices provided information as to the trade-off between an increase in bills today compared to a decrease in future bills and generate their expected rate of return on the bill increase. Figure 5 shows the distribution of the expected rate of (social) return and the frequency of individuals in that bracket.

Figure 4 Expected future rates of return and frequency of survey respondents



Source: PwC analysis

The infinity bar in Figure 5 represents the sample of respondents who were not willing to increase their bills today for any amount of benefits for future generations. Approximately 48% of the individuals in the survey behaved in this way. Since these individuals do not have an intergenerational preference, it can be assumed that they only take their individual time preferences into consideration when choosing bill profiles. Hence, it is only the individual time discount rate that is of importance to them, and this portion of the sample can be assumed to have the average social discount rate of 2.8%.

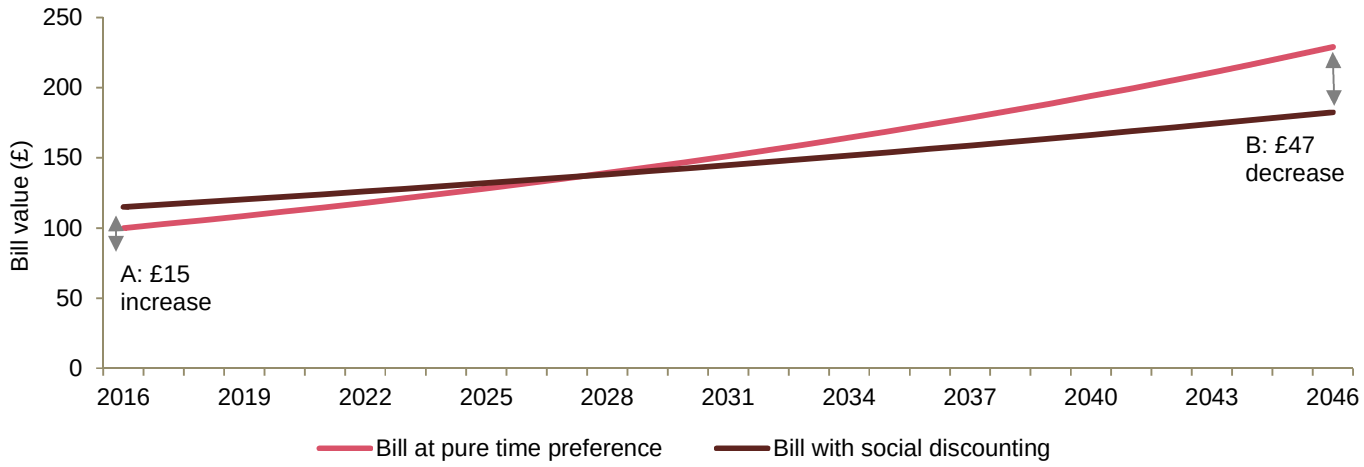
For the rest of the sample, the following methodology was used to obtain an intergenerational discount rate based on the increase in bill in 2016 that individuals today were willing to pay and their expected future (social) return for the increase in bill today.

Steps:

1. Assume the electricity bill is £100 in 2016. Using the weighted average time discount rate figure of 2.8%, the bill grows for 30 years amounting to £229 in 2046. This means that purely based on time preferences, an individual will be indifferent when faced with a £100 electricity bill today and £229 in 2046.
2. From the sample of individuals who showed sacrificial preferences towards future generations, the average increase in bill reflected in their choices was £15 in 2016. Hence, individuals today were willing to increase their bill to £115, on average, provided their expected rate of return in future bills was realised. This increase is denoted as 'A' in Figure 6.
3. For this example, it is assumed that the expected rate of return demanded by the individual today is 4%. The increase in bill in 2016 (£15) is compounded over 30 years at the expected rate of return of 4%. The result is the expected benefit i.e. a reduction in the bill in 2046 required by the individual to increase their bill today. At a 4% rate of return, the expected decrease is £47 in 2046. This is denoted by 'B' in Figure 6.
4. Hence, the new bill in 2046 after including a £47 reduction from Step 3 is £182.
5. The discount rate that compounds £182 in 2046 back to £115 in 2016 is the overall social discount rate which incorporates for the expected social rate of return of 4%.
6. This exercise is repeated for expected rates of return from 0.5% to 7% (with intervals of 0.5%).

3.3 Estimating a discount rate using primary research (Cont'd)

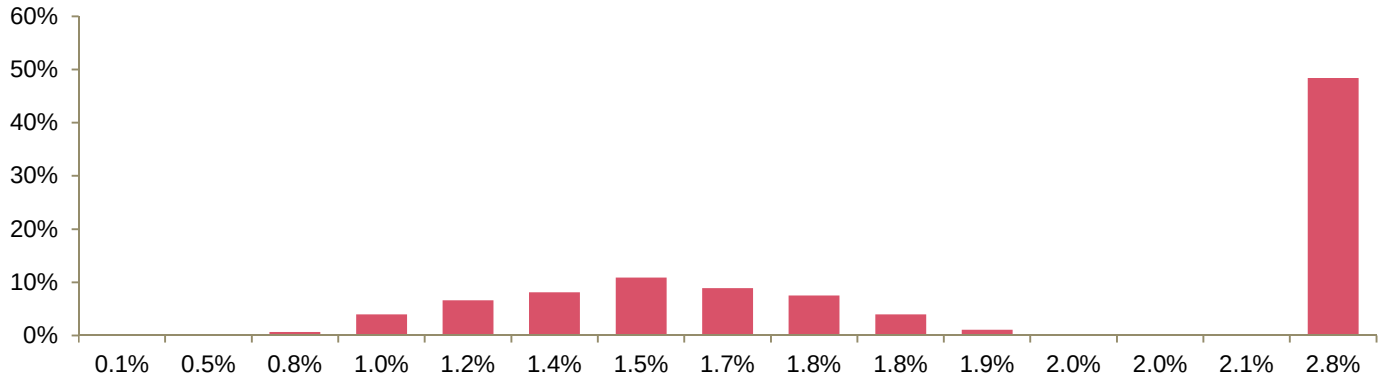
Figure 5 Illustration of estimating a social discount rate from an expected rate of return



Source: PwC analysis

The analysis repeated Steps 1 to 5 for a range of expected rates of return (shown in Figure 5). Figure 7 shows the output on the range of social discount rates obtained from running this exercise. 48% of the sample surveyed did not attach an intergenerational component to their discounting behavior – for these survey respondents s the time preference average discount rate of 2.8% was used.

Figure 6 Intergenerational discount rate estimates and frequency of survey respondents



Source: PwC analysis

The distribution of social discount rates based on survey responses is shown in Figure 7. Excluding the individuals who do not attach any intergenerational preferences, the most frequently featured intergenerational discount rate was 1.5%. This is similar to saying that the most frequently featured intergenerational rate of return was 4%. In order to estimate a social discount rate, a weighted average is taken across the frequencies and the corresponding social discount rate estimate. For example, the 2.8% discount rate is weighted with 48% of the sample, and 1.5% with 12% of the sample, and so on for all social discount rate estimates.

This results in a weighted average social discount rate of **2.14%.**

3.3.5 Conclusion from the estimate of the social discount rate from economic first principles, benchmarking and primary research

This social discount rate estimate from the conjoint analysis complements the findings from academic studies and adjusted social discount rate estimates used by policymakers (as discussed in Section 3.2 of this report). The 2.14% estimate for a risk-less social discount rate lies between the Stern report's findings of 1.4% (which was for climate change projects with benefits in 200 years' time) and the HMT Green Book of 3.5%, which was for public sector projects with a life span of less than 30 years.

Therefore, for the purposes of assessing the total cost from a consumer perspective of each of the pension strategies in report titled 'Determining the optimal strategy' we use a social discount rate (before allowing for risk) of 2.14%.

4. Incorporating risk into the discount rate

4.1 Introduction

Given their general aversion to risk, individuals and investors need to be compensated for the risk they are bearing, i.e. the possibility that the projected future benefit of an investment may not materialise. For this reason another key component of discount rates is the inherent risk premium, which quantifies the extra expected return required to bear a certain level of risk.

It is normal to add a risk premium to discount rates. Investor required returns are therefore higher for riskier projects. But when discounting bill profiles, or costs, a riskier bill profile should be reflected as an increase its effective cost (so that additional risk bears a cost). This means that the adjustment for risk is reversed when applied to costs. A risk adjustment is therefore a deduction to the discount rate.

In the context of consumer bills, it is appropriate to incorporate a risk adjustment into the social discount rate because bill payers will bear pensions risk in relation to changes in costs and benefits. Indeed there is little difference between bill payers bearing these kinds of risks and investors. However, this is not always done in appraising public sector investment projects if the Government considers such risks are fully diversified across the economy.

4.2 Definition of pensions risk

In the case of pension contributions to defined benefit schemes, given the long-term nature of pension schemes that promise benefits 40 to 50 years from today, the incorporation of risk in the estimation of the discount rate is important. In practical terms this is likely to add an extra, albeit necessary, layer to the time preference rate.

Pension risk definition

To the extent that risk is systematic (i.e. correlated with the market and cannot be diversified away by holding a diversified portfolio of securities) and appropriately reflected in the market pricing of equities, the compensation for bearing such risk is reflected in the returns investors require and expect in order to be incentivised ex-ante to provide capital. Higher systematic risks require higher ex-ante expected returns by way of compensation.

In the capital asset pricing model (CAPM), the compensation for risk is reflected by the risk premium term, which is a function of the asset beta, relative to the market portfolio, and the equity risk premium:

Expected Return = Riskfree Rate + Market Beta * Equity Risk Premium

Depending on the pension scheme a company has in place and the type of underlying assets, investors could require an extra compensation for what can be defined as pension risk.

The risks associated with a company's operating assets on the one hand, and its pension scheme on the other are not necessarily the same, and therefore it is possible that the risk and cost of capital for a firm's underlying operating assets may differ from the overall observed risk and cost of capital for the entire company, the latter figure also reflecting pension risk. The size of the divergence between the cost of capital when measured including or excluding pension risk varies with the size of the pension scheme relative to the sponsoring company: A company with a large pension scheme relative to the size of its operations has a larger distortion than a company with a smaller scheme relative to its operational size. In addition, if the risk profiles of the operating assets and the pension fund are similar, then the distortion may be small, but where the pension fund exposes investors to different risks in relation to the operating assets of company, then the distortion can be more substantial. This was first explored by economists Li Jin, Robert Merton and Zvi Bodie ('JMB'), who set out this concept and supported it with empirical findings.

Their main premise is that the difference in pension asset beta and pension liability beta constitutes a building block in the assessment of pension risk.

4.3 Estimation of the pension risk premium using economic first principles

There are two broad techniques to quantify pension risk (and its impact on the cost of capital and in particular the asset beta). One involves using empirical results for the relationship between the different size and composition of pension funds on company asset betas (the 'empirical' approach). The other was first introduced by JMB. It involves using cost of capital expressions which specifically incorporate pension risk variables.

JMB approach

According to JMB, it is unlikely that firms' systematic risk will be underestimated by the market, but because the standard approach to calculating the cost of capital does not separate out pension fund and operating assets risks, and the two types of risk generally differ in magnitude, potentially large biases in estimations of pure operating equity betas can occur. JMB suggested that such a differential can have implications for corporate finance practice in the determination of the cost of capital for capital budgeting decisions i.e. introducing the potential for incorrectly rejecting projects based on a calculated cost of capital inappropriately inflated by pension risk.

The overall systematic risk of a pension fund is based on the difference in systematic risk between its liabilities and assets. Liabilities may exhibit little systematic risk, being affected by factors such as life expectancy which may be only weakly correlated with market factors. Assets are more likely to expose the fund to systematic risk, for example if the fund invests in equities. The combination of low systematic risk liabilities and high systematic risk assets magnifies the overall systematic risk associated with the pension fund.

JMB empirically test their theory through time series analysis, restricting their sample to non-distressed firms. The results support their initial hypothesis. They conclude that the standard approach to assessing corporate discount rates (without separation quantification of pensions risk) leads to an upward bias in asset beta estimation which can have effects on capital budgeting. They suggest that adjustments to asset betas to reflect only the underlying operating asset betas will resolve this situation.

JMB's work can therefore be used to specify two relationships. The first sets out the assessment of pension risk and the second shows how to adjust the company cost of capital for pension risk.

$$\beta\_P = (\beta_{PA} - \beta_{PL})$$

$$JMB\ adjustment = \frac{PA}{D+E}(\beta_{PA} - \beta_{PL})$$

where

- βPL represents the beta of pension liabilities;
- βPA represents the beta of pension assets;
- PA represents the size of the firms' pension scheme assets (and liabilities if it is assumed that the pension fund is in balance);
- D is the firms' debt book value; and
- E is the equity capital market value.

Estimation of βPL

Pension liabilities (at any point in time) are the present value of all the future benefits to be paid to past and current employees. These claims by their nature are both long-term and contractually required (since the pension fund has legal obligations to make pensions payments). Moreover, in the event the employer defaults and the funds in the pension fund are insufficient to cover the liabilities, the protection provided by the pension regulator ensures that scheme members continue to receive almost the same level of pension payments.

Pension liabilities are generally considered by most observers to be similar in risk profile to a long duration government bond. This is because government bonds are generally considered to be very low default risk (as the government is expected to fulfil its obligations) and the long-dated maturity makes them similar to the long-term nature of pension liabilities. This suggests that a possible starting point in assessing the βPL would be the beta of a long-duration government bond.

However, pension liabilities do not have exactly the same risk characteristics as long-duration fixed income securities, as they are exposed to uncertainty surrounding expected real wage growth. This is because the ultimate amount of pension benefit depends on the final and/or average salary that a scheme member earns prior to drawing a pension. Moreover longevity risk exists as well due to the increasing life expectancy trends among policy holders and pensioners, which can result in payout levels that are higher or lower than originally anticipated.

To account for these adjustments, βPL is estimated by calculating the beta of a long-dated government bond, to which an adjustment to account for the systematic risk relating to expected real wage growth is then applied.

The beta of a long-duration index linked bond is estimated to be 0.10. Adjusting for real wage growth provides an overall assessment of βPL of 0.11.

4.3 Estimation of the pension risk premium using economic first principles (Cont'd)

Estimation of βPA

The assessment of βPA is relatively straightforward compared to the assessment of βPL as it focuses on actual assets, many of which are traded and whose betas can therefore be calculated directly. In principle βPA can be estimated by calculating the beta for each asset class invested in the company pension scheme and then by constructing the overall βPA by weighting these asset class betas in proportion to their value in the pension fund.

The list below shows the different asset classes considered in the WPD pensions strategies:

- Multi-Asset;
- Global Equity;
- UK Equity;
- International Equity;
- Bonds;
- Property;
- Absolute Return Funds; and
- Cash and others

The risk premium in relation to incremental pensions risk is determined by the asset allocation in the pension fund, assuming the pensions liability beta is constant at 0.11.

An estimate of the risk premium for a range of asset classes using the JMB approach is set-out in the following table:

Table 6 Risk premiums using economic first principles

Asset class	Risk premium (real) [2]
Equities	4.43%
Diversified growth	4.43%
Multi-asset credit	1.93%
AA-rated corporate bonds	0.33%
A-rated corporate bonds	0.43%
Portfolio of Gilts and LDI	0.93%

Source: PwC analysis.

[2] Risk premium calculated as (asset class beta less liability beta) multiplied by equity risk premium. Equity risk premium assumed to be 5% plus inflation. Liability beta assumed to be 0.11

4.4 Estimation of the pension risk premium using primary research

Analysis was also carried out to estimate the pension risk premium using primary research. Full details of the methodology and results are set-out below.

4.4.1 Statistical technique used – conjoint analysis

Conjoint is a statistical preference technique which is well established in market research and academic studies. It works by decomposing a product or service into its main value attributes and asking individuals to make trade-offs between products or services to understand the value of their underlying attributes.

4.4.2 Summary of research

The research was carried during April 2016 and included responses from 1,006 domestic electricity consumers, 1,005 business electricity consumers.

For more detail on the specific questions and profile of the respondents, see the report titled 'Investigating UK electricity consumer preferences for bearing DNO pension cost and risk.'

The survey respondents were assessed on their perception of risk by asking them to choose between bill profiles which characterised with different levels of variability and average bill value. Individuals were asked to choose a preference for a lower average bill but higher volatility in bill payments or a higher average bill with more certain bill payments.

4.4.3 Methodology

The purpose of the risk premium conjoint analysis was to validate the findings from the fundamental beta and risk premium analysis conducted in Section 4.3.

To test an individual's preferences on average bill values and the volatility of bills, they were asked a similar question to the one used to assess their time preference. The only difference was the characteristics of electricity bill profiles. In the time preference conjoint, the bill values had no uncertainty and grew at a constant rate around the intersection point in 2024. In order to test the respondent's willingness to bear risk, variability in bill values was introduced as follows:

- Six different ranges for bill variability were set out, with each range reflecting the maximum required bill payments for a 100% exposure in six potential pension asset classes for WPD.
- For example, one of the pension asset classes was equity. Based on the UK equity return it's possible to estimate the total consumer contribution had WPD invested 100% of its pension asset portfolio in equity. From there, in the situation that the electricity bill payers bore the entire contribution it was calculated what the maximum annual increase in bill per person would be to cover the entire value of the contribution, as if the consumers faced complete incidence of risk. This provided an approximate variability in bill for a 100% exposure in equity. This was repeated this for six different asset classes.
- One of the bill profiles had a constant growth rate till 2032, while the other had a volatile bill profile with constantly fluctuating bill values. Individuals were asked to choose their preferred bill choice.

4.4.4 Results

The results of the conjoint analysis for each of the six asset classes tested is set-out below

Table 7 Survey results on risk premiums for each asset class included in the conjoint analysis

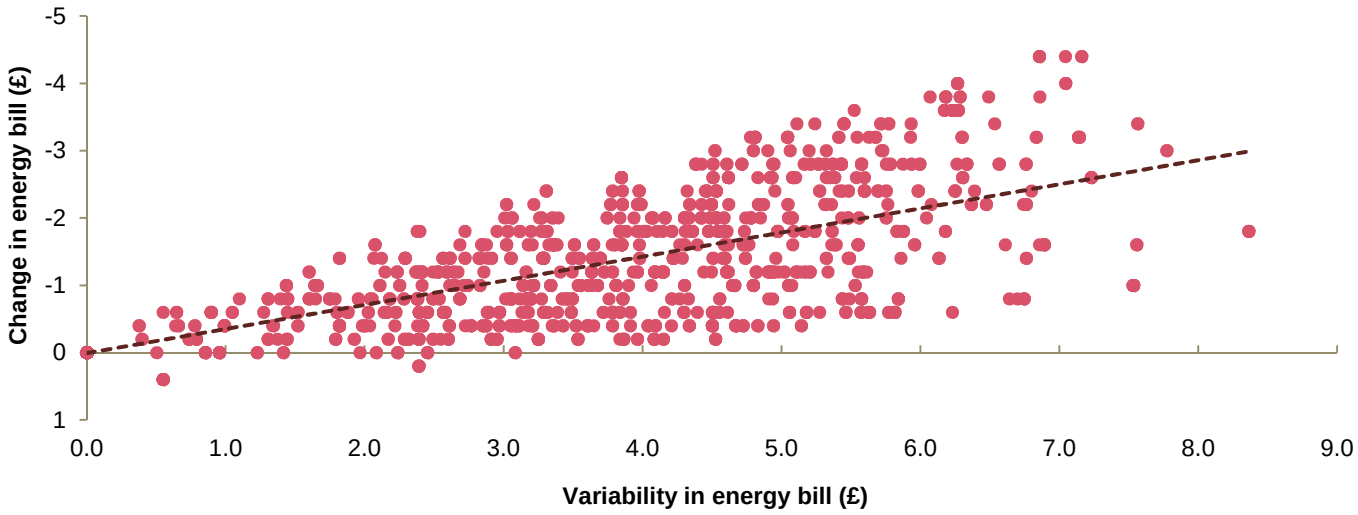
Asset class	Risk premium (real)
Equities	4.45%
Diversified growth	4.35%
Multi-asset credit	1.80%
AA-rated corporate bonds	0.30%
A-rated corporate bonds	0.55%
Portfolio of Gilts and LDI	0.78%

The variability in the electricity bills was based on the expected risk variability of the asset classes which was then presented to the consumers surveyed in terms of the impact on their electricity bill. The table shows that the highest risk premium is for the equity assets and the lowest for AA rated bond asset. The DGF is a fund that has equity like characteristics. Hence, it is not surprising that individuals view the variability from equities and DGF's similarly. Variability in bills due to corporate bonds was perceived to have the lowest risk premium in the set of asset classes assessed.

In addition, the conjoint analysis provided the average risk premium across the consumers surveyed for an average level of risk. The results of this are set-out in Figure 8 below which shows a gradually increasing trend as variability in electricity bill increases on average, individuals demand a greater reduction in the expected value of their electricity bill.

4.4 Estimation of the pension risk premium using primary research (Cont'd)

Figure 7 Survey responses on risk premiums in bill value terms



Source: PwC analysis

The line of best fit of the data obtained indicates that on average, individuals demand a 35p reduction in the expected value of the electricity bill for a £1 increase in variability. The trade-off between the change in expected value and variability is the slope of the line of best fit in the figure above.

Every data point in Figure 8 represents an individual's variability threshold for a given change in energy bills. The risk premium is the premium on the base discount rate required to match bill profiles with this desired level of variability and expected change in bills. Comparing all the survey results suggests that the average individual price of risk or risk premium was 2.4%.

4.5 Conclusion from the estimate of the pension risk premium from economic first principles and primary research

The table compares the risk premiums calculated from the primary research with the risk premiums calculated from economic first principles

Asset class	Risk Premium using economic first principles	Risk Premium using primary research
Equities	4.43%	4.45%
Diversified growth	4.43%	4.35%
Multi-asset credit	1.93%	1.80%
AA-rated corporate bonds	0.33%	0.30%
A-rated corporate bonds	0.43%	0.55%
Portfolio of Gilts and LDI	0.93%	0.78%

The findings on the risk premiums emerging from the conjoint analysis validates the risk premiums calculated from economic first principles.

Therefore, for the purpose of calculating the pension risk premium element of the social discount rate the risk premium derived from economic first principles will be used as this formulaic approach enables the calculation of pension risk premium to be calculated for a wider set of asset classes and portfolios.

It is normal to add a risk premium to discount rates. This reduces values as individuals and investors are typically risk averse and require compensation for bearing risk. But when discounting bill profiles, or costs, a riskier bill profile should reflected as an increase its effective cost (so that additional risk bears a cost). This means that the adjustment for risk is reversed when applied to costs. A risk adjustment is therefore a deduction to the discount rate.

5. Conclusion

5. Conclusion

After considering the academic literature available, benchmarking from other studies into social discount rates and the results of primary research via conjoint analysis, the weighted average pure time preference discount rate of an individual in the UK was found to be 2.8%. Furthermore, the social discount rate was found to be 2.14%. Both of these results were the conclusions of statistically significant market research using conjoint analysis techniques and were validated by the academic literature and aligned with benchmarking on other studies into social discount rates.

The evidence from both academic studies and discount rates used in other policy decisions suggests a similar figure of around 2%. This is between figures obtained from the first principles approach, and with the updated/modified estimate from the Green Book (2003) and Zhuang et Al (2007), adjusted for the movements in market variables since their publication. The 2.14% figure is also above the Stern report figure, which was used for very long-term persisting benefits in contrast to changes in WPD's pension contributions, which are not as long-term and will ultimately fade.

In addition, the primary research using conjoint analysis to assess the pension risk premium adjustment to the social discount rate validated the calculation of the pension risk premium from economic first principles. Therefore, for the purposes of calculating the social discount rate including risk premium the economic first principles approach will be used as this enables the calculation of risk premiums for a wider set of asset classes which will be required for assessing the long-list of pension strategies set-out in report titled 'Long-list of pensions strategies'.

As sample of the pension risk premiums for six asset classes using economic first principles are set-out below:

Asset class	Risk premium (real)
Equities	4.43%
Diversified growth	4.43%
Multi-asset credit	1.93%
AA-rated corporate bonds	0.33%
A-rated corporate bonds	0.43%
Portfolio of Gilts and LDI	0.93%

Source: PwC analysis.

6. Appendices – Appendix A: Literature review on individual and social discount rates

A.1 Time preference discount rate

There are different factors that can influence individuals' time preference, impatience and, as a consequence, discount rates[1]. Academic studies have identified age, income, health and mortality risk as the most relevant factors. The following sections provide a description of their impact in turn.

A.1.1 Demographic variables

Age

Academic studies are not very conclusive on the direction of the impact that age has on the time preference discount rate.

Negative relationship between age and discount rate

Green, Fry and Myerson (1994) found evidence for a negative relationship between age and the discount rate. They performed an experiment on 36 members from 3 age groups (12 sixth graders with an average age of 12.1 years, 12 college students with an average age of 20.3 years and 12 older adults with an average age of 67.9), who had to choose between immediate and delayed hypothetical monetary rewards. Participants made a series of choices between the fixed-amount reward (e.g., $1,000) that could be obtained after a delay (eight possible delays: 1 week, 1 month, 6 months, 1 year, 3 years, 5 years, 10 years, and 25 years) and an immediately obtainable reward that varied in amount (30 values between $1 and $1,000). In this manner, for example, the participants would have to make a choice between $1000 in 10 years or $650 now.

For each fixed amount at each delay and each participant, a subjectively equivalent immediate amount was determined. The analysis concluded that for any given delay at which a fixed amount of money (e.g. $1000) was received, the discounted value of the fixed delayed reward was lower for children than for young adults and it was lower for young adults than for older adults. Relative to adults, children will accept a smaller, immediate reward in place of a large, delayed alternative, and will wait a shorter time for a large reward when they could instead choose a small, immediate reward.

Positive relationship between age and the discount rate

On the other hand Trostel and Taylor (2001) used micro-level longitudinal consumption data in the U.S. in their analysis and found a statistically significant negative relationship between age and consumption growth (where higher consumption growth was assumed to reflect a lower discount rate). This is equivalent to a positive relationship between age and the discount rate.

This supports the hypothesis that people generally prefer present consumption to future consumption because their expected utility from consumption (eventually) falls as their mental and physical ability (eventually) declines with age. According to this view discounting occurs because of the lower marginal value of consumption in the future, which is due in turn to the fact that the ability to enjoy consumption decreases with time. For a given delay, older people will have a higher discount rate than young people, given that the expected rate of decline of marginal utility should be increasing with age.

No relationship between age and the discount rate

Chao, Szrek, Pereira and Pauly (2009) analysed how discount rate, measured by presenting participants with a set of hypothetical choices between smaller immediate rewards and larger later rewards, is related to age, health, and survival probability. The sample of individuals was based in townships around Durban, South Africa. In contrast to previous studies, the result was that age is not significantly related to the discount rate, but both physical health and survival expectations have a U-shaped relationship with the discount rate.

Health and survival probability, and not age, seem to be better predictors of discount rates in an area of the world with high morbidity and mortality, because causes of morbidity and mortality in South Africa are not necessarily related to age, age is no longer a strong predictor of health and expected survival and, hence, of discount rates.

U-shaped relationship between age and discount rate

Harrison et al. (2002) elicited discount rates among 268 people between the ages of 19 and 75 drawn from a nationally representative sample in Denmark. Although there initially seemed to be a U-shaped relationship between discount rate and age, after having controlled for other demographic characteristics, the regression results showed no statistically significant differences in discounting between people in different age brackets. The regression did show, however, that those who were retired (and hence among the oldest in the sample) had significantly greater discount rates than those still working, in line with Trostel and Taylor (2001).

[1] A 'best practice', comprehensive search strategy was applied in order to collate the academic studies as part of the literature review. The literature has been narrowed to peer reviewed journal publications, guidance documents and academic papers. The aim being to present some of the latest evidence from documents with iterations. Some of the keyword searches to gain access to these papers include social discount rate, declining discount rate, discounting for cost benefit analysis, cost of capital in pension risk

A.1 Time preference discount rate (Cont'd)

Read and Read (2004) also conducted a study designed specifically to test the relationship between discount rate and age, by surveying 123 UK respondents selected using a quota sample of three distinct age groups consisting of the young (mean age of 25), middle-aged (44), and elderly (75). Although the study mostly confirmed the theoretical predictions of Sozou and Seymour (2003), i.e. a significant U-shaped relationship between discount rate and age for monetary rewards, after having controlled for other demographic variables, both the linear and the quadratic terms for age were insignificant.

Therefore, despite being an appealing hypothesis, a U shaped relationship between age and discount rate has limited support from rigorous econometric analysis in academic studies.

Income

It is generally accepted in academic studies that poor individuals often exhibit higher discount rates than richer individuals, and both negative income shocks and low levels of income have been linked to increases in discount rates. However, there are linkages between wealth and mortality and risk, which, means it can be difficult to determine which factor is driving discount rates. The causality in this relationship and the impact that income has on preference have been investigated and proved by Haushofer, Schunk and Fehr (2013).

Because of the difficulty of studying income shocks while holding wealth constant, the study takes a laboratory approach, which allows researchers to study the effect of shocks while holding individual wealth constant, by both random assignment of wealth, and comparison of an income shock group to a control group with the same absolute wealth level.

The experiment involved 148 healthy male participants from the University of Zürich being randomly assigned to one of four 'treatment conditions', unbeknown to them: 'always rich'; 'always poor'; 'negative income shock'; and 'positive income shock'. Individuals were then asked to play a game that would affect their score, while constantly being informed of their current wealth and ranking in the group through bars and numbers. At a certain point throughout the game the two income shock groups received their unanticipated income shocks. Participants had been told they might experience a sudden change in wealth levels, but the timing, magnitude and direction of these was unknown.

The magnitude and direction of the income shock for the 'negative income shock' group was such that the post-shock average wealth of this group was equal to the pre-shock average wealth of the 'always poor' group. Similarly, the magnitude and direction of the income shock for the 'positive income shock' group was such that the post-shock average wealth of this group was equal to the pre-shock average wealth of the 'always rich' group.

This allowed comparing the effect of income shocks on economic choice, holding constant current wealth: comparing the behaviour of the 'negative income shock' group to the 'always poor' group revealed in fact the effect of a negative income shock, holding constant current wealth, while comparing the behaviour of the 'positive income shock' group to the 'always rich' group revealed the effect of a positive income shock, again holding constant current wealth.

From the experiment it can be seen that participants in the 'negative income shock' group exhibit greater post-shock discounting than participants in the 'always poor' group. Positive income shocks also result in a decrease in discount rate.

Health and mortality risk

The few studies that have included proxies for health have mostly included only dichotomous or linear terms for it, which may not be sufficient if health, like age, could be non-linearly related to the discount rate. However, Kirby et al. (2002) found no relationship between body mass index and the subjective discount rate. Read and Read (2004), using two dichotomous variables for health (good vs. bad health; disease in last year vs. not), found poor health to be unrelated to discounting for monetary rewards, but related to discounting of a vacation reward.

While analysing how the discount rate is related to age, health, and survival probability Chao, Szrek, Pereira and Pauly (2009) however found that physical health, but not mental health, has a significant U-shape relation with the discount rate. This could be a reflection of the fact that healthy people enjoy consumption when they can, while people with very poor health may have more immediate need of cash to pay for medical care, and thus save less.

After controlling for mortality risk the magnitude and the significance level of the physical health variables decreased, suggesting that part of the effect of the health variable on discount rate was via the relationship between health and survival. Although the linear term for physical health was no longer significant when including both a survival rate variable and a sociodemographic variables, the quadratic term remained significant at the 10%.

A.1 Time preference discount rate (Cont'd)

The analysis also showed a very robust U-shaped relationship between the discount rate and survival probability, even after controlling for current physical and mental health status. This is in contrast with Trostel and Taylor (2001), who showed that mortality risk over the life cycle does not cause an increase in discounting. According to Chao, Szrek, Pereira and Pauly (2009) it is reasonable for people with low expected survival to have a high discount rate, because their future consumption may never happen.

Education

Bozio, Laroque and O'Dea (2014) found that less educated families and families with lower levels of numerical ability tend to be more patient than with more education and greater levels of numerical ability respectively. This can reflect the fact that families that are more educated are likely to have higher future salary expectations, and thus be willing to save less if some unexpected positive income shock occurs.

A.1.2 Impatience (shape of time preference)

Future cash flows are discounted according to a discount function, which determines the present value trend, in relation to the different delays of the future rewards. The discount rate literature focusses on two main discount functions: hyperbolic discounting and exponential discounting.

Hyperbolic discounting refers to the tendency for individuals to increasingly choose a smaller-sooner reward over a larger-later reward. When offered a larger reward in exchange for waiting a set amount of time, people act less impulsively (i.e., choose to wait) as the rewards happen further in the future. Expressed differently, individuals avoid waiting more as the wait gets closer to the present time. This functional form is supported by Green, Fry and Myerson (1994) who found evidence that the rate at which individuals discount future hypothetical money rewards increases faster when the delay is shorter. Moreover, according to the paper, increases in delay produce greater decreases in the present value of smaller future rewards than of larger rewards, across all the age groups analysed (i.e. children, young adults and older adults). In summary individual impatience tends to be higher over short delays than longer time horizons, and when future rewards are larger.

The other common functional form used in academic studies is exponential discounting, which assumes a constant discount rate over time. This functional form still captures impatience, but the rate of change in impatient does change when considering different time periods. This approach is widely used by companies in discounting future cash flows, given the easiness of dealing with a constant discount rate.

A.1.3 Future generations

There is an ongoing debate regarding intergenerational discounting. One of the potential drawbacks of exponential (and particularly hyperbolic) discounting is that it allocates very little value to consumption for future generations. Some academics suggest this is unfair to give less weight to the same level of consumption of any future generation on the grounds of individuals, or society as a whole, being impatient.

Conversely, the rationality of discounting is, according to other opinions, technically superior to the objections about intergenerational fairness or equity.

There have been a number of attempts in the academic literature to reconcile the rationality of exponential discounting to the potential fairness of lower discounting when the benefits will be experienced by future generations. The following sections describe them in turn.

Low discount rates

One suggested solution to give a fair value to benefits experienced by future generations is to discount the far distant future with very low discount rates, as shown by Weitzman (1998). Gollier, Koundouri and Pantelidis (2014) also show that when uncertainty is taken into account, the case for the use of Declining Discount Rates (DDRs) in long-run cost–benefit analyses becomes compelling. This is consistent with a view that policy-makers should view improved social welfare in the far distant future highly in comparison to short time welfare improvements.

To provide a series with reducing longer-term discount rates, many researchers to use regime-switching models in describing the entire term structure of interest rates (e.g., Bansal and Zhou, (2002) and Gollier, Koundouri and Pantelidis (2008)).

A.1 Time preference discount rate (Cont'd)

Distributional weights

According to Scarborough (2010), concerns regarding the well-being of future generations can be addressed through the application of intergenerational distributional weights rather than low social discount rates. This means that in a social, as opposed to an individual context, the intergenerational equity-adjusted present value of benefits and costs is the discounted future value multiplied by some distributional weights higher than one.

Scarborough and Bennett (2008) designed a choice experiment to estimate intergenerational distributional preferences found that, over two generations, society has positive preferences toward future generations. The estimated distributional weights are approximately 1.6 over one generation and 2.2 over two generations. A project with a current cost of $100 and a future benefit in 25 years' time of $200, would not be feasible in net present value terms with a 5 percent discount rate (NPV of benefit is $75). However, with the application of a distributional weight of 1.6 the future benefit is $120 and the project becomes feasible.

How to discount intergenerational projects

Hallegatte (2008) proposed a prescriptive consumption discounting scheme that applies different discount rates or various incomes in the lifetime of a unique individual and for various incomes that affect different individuals. Practically, any income flux is first discounted to the birth date of all individuals using a discount rate with a non-zero pure preference for the present; then these individual discounted values are discounted to the present with a discount rate with no preference for the present and finally summed up.

According to the scheme proposed in this report at a theoretical level, as suggested by Hunt and Taylor (2008), current-generation consequences are not discounted at the same rate as intergenerational consequences. Each individual is considered separately. The flux of income that each individual will receive is first discounted to the birth date of this individual. This discounting is done using the usual discount rate, which takes into account a non-zero pure preference for the present and the effect of economic growth and is consistent with observed behaviours. Then, these discounted values are discounted to the present and summed up. Since this second discounting phase considers different individuals, born at different times, there is no reason to consider a non-zero pure preference for the present (especially because the risk that mankind may disappear is disregarded). This second discounting is done, therefore, using a discount rate that takes into account only the effect of real-consumption growth.

This scheme, therefore, makes a transition between the observed short-term discount rate, usually higher, and an ethically acceptable long-term discount rate, which is significantly lower. This transition by a fundamental difference between individual discounting and intergenerational discounting.

A.2 Risk aversion and risk premium

In addition to time preference, risk parameters should also feature in building a discount rate. In the context of assessing the impact of pension risk, the impact of pensions risk is reviewed from perspective of the electricity bill payer's perspective and pension risk premium from an investor's perspective.

Most studies on social discount rates assume only a rate of pure time preference and exclude the element of risk in consumer choice.

However, such an approach can be misleading. Regardless of WPD's management of pension assets and liabilities, pension risk will be borne by at least of the company, the pension beneficiaries or individual bill payers. In this regard, the risk relating to the pension scheme can be moved around. In this case the risk premium for bearing pension risk may move, but can't be eliminated.

A.2.1 Risk aversion – An individual's perspective

Definition

Risk aversion refers to a general dislike for risk such that when an investor is faced with two investments with a similar expected return, but different risks, the investor will prefer the one with the lower risk.

Ding, Hartog, Sun (2010) tried to assess individual risk attitudes by testing them on a real lottery, i.e. on a lottery with pay-out in real money. An experiment among students of PKU in Beijing was set up where students were presented with four opportunities to participate in a real lottery which they could forgo by receiving a cash payment. The experiments found confirmation of risk aversion which has been established in other academic studies.

However, although people are usually risk-averse in dealing with even very unlikely losses, they often become risk-seeking when dealing with improbable gains. When respondents in the study received 100 yuan and then were offered the choice to pay 20 yuan or play a lottery with a possible outcome of -100 yuan, i.e., the obligation to pay 100 yuan, the majority chose the riskier option, i.e. the lottery.

Relationship between risk aversion and time preference

Academic studies have also tried to understand how risk aversion affects the time preference discount rate.

Praag and Booij (2003) analysed a large sample of individual responses to six lottery questions. A simultaneous estimate of risk aversion, in a Constant Relative Risk Aversion (CRRA) function setting, and the time preference discount rate per individual were derived. It was found that the parameters are moderately negatively correlated (-0.35).

The negative correlation between the risk aversion coefficient and the time preference discount rate indicates firstly that the two concepts are clearly separately identifiable. The next section discusses this aspect further, describing a methodology to isolate the impact of risk on the discount rate from the other components. Secondly the study shows that high-risk aversion goes hand in hand with low time period discounting. This is precisely what can be expected of prudent people. They take few risks and they look a long time ahead.

The report also investigated how different variables affect both the coefficient of risk aversion and the time preference discount rate. Risk aversion declines with increasing income as the same monetary risk becomes relatively less important when income increases. For the same reason individuals with a lot of income will use a higher time discount rate to evaluate the windfall profit of a lottery prize.

With respect to age, it seems that older people are more settled and hence can take more risks (lower coefficient of risk aversion). This is also reflected by a more impatient attitude and a higher discount rate.

6. Appendices – Appendix B: Weighted average discount rate

B.1 Time-varying and/or weighted average discount rate

An alternative approach to using a single social discount rate is to use a time varying or weighted average discount rate. This involves using separate discount rates for future pension benefits for segregated subsets. For example, different discount rates could be adopted for benefit obligations for active pension participants, terminated participants and retirees. Alternatively, there could be a different discount rate for current electricity bill payers compared to future bill payers. These different discount rates can then be combined or weighted to obtain a single discount rate for each time period. This approach is consistent with that set out by Hallegatte (2008). Such an approach could incorporate the evolution of discount rates for age, health and other factors identified in Chapter 3.

The implications of addressing the sensitivities of present (short-term) consumption as well as intergenerational equity requires a declining, weighted average discount rate. Suppose the future comprises two social discount rates of 5% and 2%. Discount factors for both these rates are shown in Table 2. For representational purposes, the discount factors have been averaged to represent a 'certainty equivalent discount factor' and estimating backwards, a 'certainty equivalent discount rate' is obtained, which starts at 3.5% and gradually reduces to 2.7% over time. One key assumption made in this approach is that the discount rate is persistent, so that the discount rate in one period is correlated with the discount rate in the previous period. If this assumption holds, the best representation of intergenerational efficiency is using a declining social discount rate instead of a single social discount rate.

Table 2 Illustration of a weighted average discount rate

Time (years from present)	1	10	50	100
Discount factor for 2% rate (middle aged individual)	0.98	0.82	0.37	0.14
Discount factor for 5% rate (young individual)	0.95	0.61	0.09	0.01
Certainty equivalent discount factor	0.97	0.72	0.23	0.07
Certainty equivalent discount rate	**3.5%**	**3.4%**	**3.0%**	**2.7%**

Source: PwC analysis

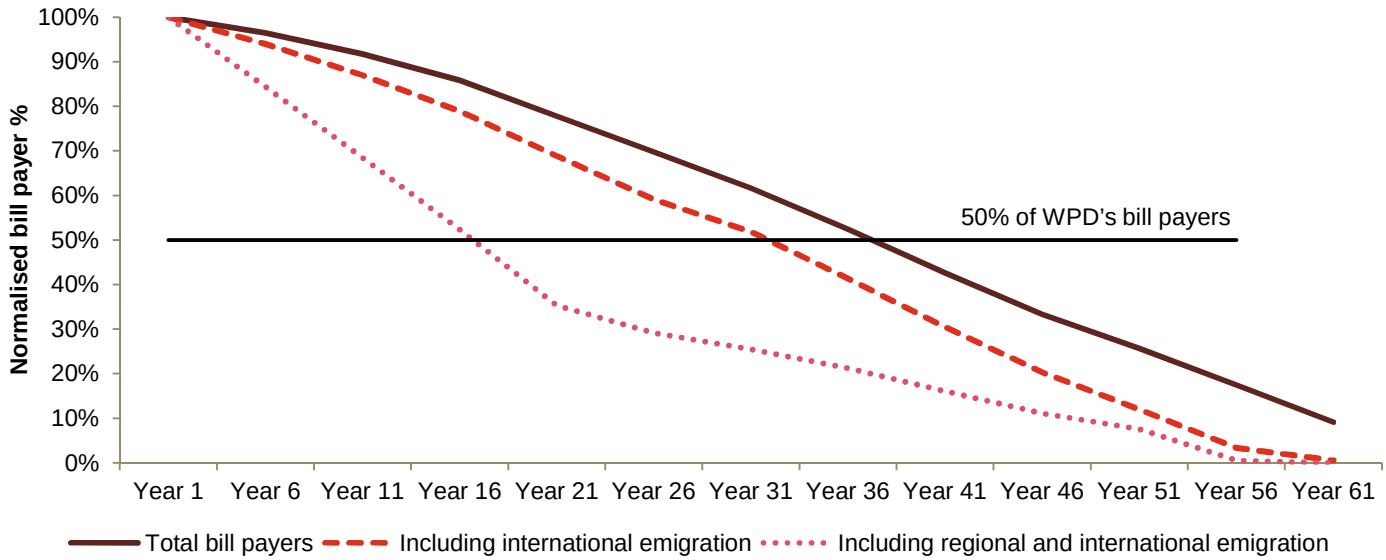
One of the ways of representing a weighted average discount rate is by using the collective preferences of individual discount rates. This report is particularly interested in the blend between current bill payers and future bill payers over time and the following analysis demonstrates the likely evolution in WPD's consumer base.

WPD's consumer age range is assumed to be from 20 to 85 years. This assumption is drawn from the average UK mortality age of 82 years, as per the latest census published by the Office of National Statistics. Figure 4 shows the estimated path of WPD's current bill payers over time, assuming that there is no further addition to their bill paying population. The downward sloping line of bill payers represents the normalised number of people who are still paying WPD's electricity bills and excludes the population that would be no longer alive to meet the bill obligations. At Year 1, the entire population in South West England, Wales and Midlands pay WPD electricity bills and their representation is normalised at 100%. As time passes by to Year 61, very few people from the initial population are alive to pay WPD electricity bills.

It is important to recognise that not all UK household occupiers are permanent residents. A significant portion of the population are temporary residents, who have the flexibility of moving across regions and countries. The movement of bill payers is not just restricted to movement outside of WPD's operating areas (which is referred to as regional emigration) but also applies to international emigration. For example, a resident in South West England using WPD's services receives a job offer from Paris and emigrates overseas. This regional and international emigration is represented in Figure 4.

B.1 Time-varying and/or weighted average discount rate

Evolution of WPD's bill payers over time



Source: Office of National Statistics, PwC analysis.

Figure 4 shows that with the combined influence of aging consumers and both international and regional emigration, only half of WPD's current consumers are expected to still be WPD consumers after 16 years. This means that surprisingly quickly the social discount rate becomes the dominant portion of any blended discount rate.

Whether to use a weighted average discount rate depends on how different the blended individual discount rate is to the social discount rate. There are a number of reasons to suggest that it will be little different:

- The profile of costs and benefits arising from pension changes is long-term in nature. This means that high short-term individual discount rates are not relevant.
- An individual average discount rate of 2.8% is not outside the range from some of the social discount rate estimates (Figure 3 shows a range of 1% to 4% with a higher outlier).
- The opportunity cost of the foregone benefits is likely to be set by a long-term investment return. This won't be the case for those consumers with no long-term savings, who may have a higher individual discount rate. A good proxy for a long-term investment return is given by fixed rate bonds in the retail savings market, or bond returns in investment products. Both are currently in the 2% to 3% range, which is barely positive in real terms. This leaves a significant uplift to allow for individual time preference.

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