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Retirement savings management: the 4% rule and the FIRE (Financial Independence, Retire Early) movement. A European and Italian case study

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Abstract

The FIRE (*Financial Independence, Retire Early*) movement and the “4% rule” have gained global popularity as a strategy for early retirement. However, these concepts were developed in the US context: this thesis analyses their applicability to the European and Italian context.

The study employs Monte Carlo simulations with a *block bootstrap* technique on historical data from the 2000–2025 period, analysing 161 distinct scenarios for a total of 16.1 million simulations. The portfolios examined combine equity indices (MSCI World, ACWI, Europe, EMU) with European government bonds (German Bunds, Italian BTPs), testing various allocations and withdrawal rates (3%, 3.5%, 4%).

The results show that the 4% rule does not reach the 95% safety threshold in any of the European scenarios tested, with a maximum success rate of 80.46%. Only with a 3% withdrawal rate and a globally diversified portfolio does the success rate exceed 95% (MSCI World: 95.82%, ACWI: 95.30%); purely European indices never reach this threshold, even at 3% (MSCI Europe: 90.13%, MSCI EMU: 86.20%).

Geographic diversification proves decisive: investing exclusively in European rather than global markets reduces the success rate by 13–17 percentage points. The 60/40 allocation appears optimal. For the bond component, a Bund/BTP mix appears preferable to diversify sovereign risk.

In conclusion, for a European investor pursuing financial indepen-

dence, a 3–3.5% withdrawal rate, global diversification, and a significant bond component appear necessary to achieve high probabilities of success.

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Chapter 1

The business problem

Terminological note: this thesis uses technical terminology from financial markets and personal finance, largely of Anglo-Saxon origin. The main terms and acronyms are defined at their first occurrence in the text or in footnotes. For further reading on financial terminology, see the Borsa Italiana glossary (Borsa Italiana [2025](#)) and the Investopedia dictionary (Investopedia [2025](#)).

1.1 The European and Italian pension landscape

The European pension landscape is undergoing a phase of profound transformation. Population ageing, combined with increasing life expectancy and declining birth rates, poses significant challenges to the sustainability of public pension systems. In this context, the concept of financial independence and the possibility of early retirement relative to the statutory retirement age is gaining increasing relevance.

1.1.1 The Italian pension system

The Italian pension system is based on a pay-as-you-go model, in which the contributions of active workers fund the benefits of current retirees.

This model, historically effective in contexts of demographic and economic growth, now shows evident structural limitations.

The Fornero reform of 2011 introduced significant changes:

- Transition to a contribution-based system for all workers
- Progressive increase of the retirement age
- Linking of the retirement age to life expectancy
- Introduction of early retirement with penalties

The replacement rate, i.e. the ratio between the first pension payment and the last salary, is in constant decline. For workers with careers entirely under the contribution-based system, the replacement rate stands at around 60–65%, significantly lower than under the previous earnings-based system.

1.1.2 The pension gap

The pension gap represents the difference between the desired retirement income and that actually guaranteed by the public system. This gap is particularly pronounced for:

- **Self-employed workers:** with lower contribution rates compared to employees
- **Discontinuous careers:** periods of unemployment, part-time work or work abroad
- **Younger generations:** entirely under the contribution-based system with lower replacement rates

According to OECD (Organisation for Economic Co-operation and Development) data (OECD 2021), the Italian pension system, while being among the most generous in the OECD area in terms of public expenditure, faces long-term sustainability challenges that make supplementary personal savings and investment appropriate. Constantly increasing life expectancy (ISTAT 2023) further amplifies this issue, extending the retirement period to be funded.

1.2 The FIRE movement and the 4% rule

1.2.1 Origins and principles of the FIRE movement

The FIRE (*Financial Independence, Retire Early*) movement represents a life philosophy and financial strategy that aims to achieve economic independence in significantly shorter timeframes than the traditional career path. The intellectual roots of the movement can be traced to the book *Your Money or Your Life* by Vicki Robin and Joe Dominguez (Robin and Dominguez 1992), which introduced the concept of “financial independence” as an achievable goal through mindful consumption. Born in the United States in the 1990s, the movement has gained global popularity through blogs, podcasts and online communities, with significant contributions such as *The Simple Path to Wealth* by J.L. Collins (Collins 2016).

The fundamental principles of FIRE include:

1. **High savings rate:** typically between 50% and 70% of net income
2. **Passive investing:** predominantly in low-cost index funds
3. **Mindful frugality:** optimising expenses without sacrificing quality of life

4. Calculating the “FIRE number”: the capital needed to sustain expenses indefinitely

The “FIRE number” is typically calculated as 25 times the expected annual retirement expenses, based on the 4% rule:

$$\text{FIRE number} = \frac{\text{Annual expenses}}{\text{SWR}} = \frac{\text{Annual expenses}}{0.04} = \text{Annual expenses} \times 25 \quad (1.1)$$

1.2.2 The 4% rule: origins and foundations

The “4% rule”, also known as the *Safe Withdrawal Rate* (SWR), derives from the pioneering study by William Bengen in 1994 (Bengen 1994) and the subsequent “Trinity Study” conducted by Cooley, Hubbard and Walz in 1998 (Cooley, Hubbard, and Walz 1998).

These studies, based on historical US market data from 1926 to 1995, determined that a retiree can annually withdraw 4% of their initial portfolio, adjusting the withdrawal for inflation in subsequent years, with a probability exceeding 95% of not exhausting the capital over a 30-year horizon.

The key assumptions of the original study include:

- Portfolio composed of US equities (S&P 500, *Standard & Poor’s 500*¹) and US government bonds
- 30-year time horizon
- Annual portfolio rebalancing
- Withdrawals adjusted annually for inflation

¹Equity index comprising the 500 largest companies listed on US stock exchanges, considered the main indicator of US stock market performance.

1.2.3 Criticisms and limitations of the 4% rule

In subsequent years, several studies have highlighted limitations of the 4% rule:

1. **US home bias²**: the original studies are based exclusively on US market data, historically among the best-performing in the world. As documented by Dimson, Marsh and Staunton (Dimson, Marsh, and Staunton 2002; Dimson, Marsh, and Staunton 2023), US market returns in the 20th century represent an exception rather than the norm globally.
2. **Sequence of returns risk**: the risk that negative returns in the early years of retirement irreversibly compromise the portfolio. Kitces and Pfau (Kitces and Pfau 2015) have demonstrated how this risk is particularly critical and suggest dynamic asset allocation strategies to mitigate it.
3. **Longer time horizons**: for those aspiring to early retirement (40–50 years of withdrawal), 4% may be too aggressive. Milevsky and Robinson (Milevsky and Robinson 2005) have developed analytical models linking the sustainable withdrawal rate to expected longevity.
4. **Low-rate environment**: current bond yields are significantly lower than historical averages. Finke, Pfau and Blanchett (Finke, Pfau, and Blanchett 2013) have shown that in a low-return environment the 4% rule is no longer safe, suggesting lower rates.

Wade Pfau, in particular, has demonstrated that applying the Trinity Study methodology to international markets yields significantly lower success rates (Pfau 2010).

²Home bias: the tendency of investors to overweight securities from their domestic market, at the expense of international diversification.

1.3 Specific challenges of the European and Italian context

1.3.1 Differences in financial market returns

One of the main criticisms in applying the 4% rule to the European context concerns the historical differences in financial market returns. The US stock market has historically outperformed European markets, benefiting from:

- Greater economic dynamism and technological innovation
- Market size and liquidity
- The role of the dollar as a global reserve currency
- Lower impact of sovereign debt crises

European markets, particularly those in the Eurozone, have been affected by the sovereign debt crisis (2010–2012) and show greater fragmentation compared to the US market (Cukierman 2016). The MSCI EMU (*Economic and Monetary Union*) index, representing Eurozone markets, has recorded significantly lower performance than the MSCI World over the 2000–2025 period. Italian investors also show a preference for domestic government bonds, exposing themselves to geographic concentration risk (Banca d'Italia 2024).

1.3.2 Italian tax aspects

The Italian tax system has characteristics that significantly impact FIRE planning:

- **Financial income taxation:** 26% rate on capital gains and dividends (12.5% for government bonds)
- **Stamp duty:** 0.2% per annum on securities account value
- **Tax-advantaged account limits:** Italy offers pension funds with tax advantages, but the deductibility is limited to EUR 5,300/year (from 2026), significantly lower than US limits (401(k)³: over USD 23,000/year)

These factors reduce the net investment return and must be considered when calculating the appropriate SWR.

1.3.3 The role of inflation

Inflation represents a critical factor in retirement planning. The euro area has historically recorded lower inflation rates than the US, but recent events (2022–2023 energy crisis) have shown the system’s vulnerability to inflationary shocks.

For this analysis, the HICP (*Harmonised Index of Consumer Prices*) for the euro area, published by Eurostat, was used, providing a harmonised measure of inflation across the Eurozone.

1.4 Research questions

Based on the analysis of the context, this thesis aims to answer the following research questions:

1. **Applicability of the 4% rule:** is the 4% rule applicable to the European and Italian context, considering the differences in historical market returns?

³401(k): US defined-contribution pension plan that allows workers to set aside a portion of their salary with significant tax advantages.

2. **Optimal Safe Withdrawal Rate:** what safe withdrawal rate is appropriate for a European investor, with particular reference to the Italian case?
3. **Impact of geographic diversification:** how much does the choice between domestic (Europe/EMU) and global (MSCI World, MSCI ACWI⁴) investment affect the sustainability of the withdrawal plan?
4. **Optimal asset allocation:** which combination of equities and bonds maximises the probability of success in the European context?
5. **Bond component choice:** for an Italian or European investor, is it preferable to use German Bunds⁵, Italian BTPs⁶ or a mix of both?

⁴ACWI: *All Country World Index*, an index that includes both developed and emerging markets.

⁵Government bonds issued by the Federal Republic of Germany, considered the benchmark for Eurozone government bonds.

⁶Buoni del Tesoro Poliennali (BTPs): medium- to long-term government bonds issued by the Italian Republic.

Chapter 2

Methodology

2.1 Methodological approach

This research adopts a quantitative approach based on Monte Carlo simulations (Glasserman 2003) with a *block bootstrap* technique (Efron and Tibshirani 1993). This methodology allows the generation of a large number of possible scenarios, preserving the temporal correlations present in historical data, to evaluate the probability of success of different withdrawal strategies.

The analysis differs from traditional studies in three main aspects:

1. **European focus:** use of European equity and bond indices
2. **Bond component:** comparison between core (German Bunds) and peripheral (Italian BTPs) Eurozone government bonds
3. **European inflation:** use of the euro area HICP rather than the US CPI (*Consumer Price Index*)

2.2 Data used

2.2.1 Equity indices

The following equity indices were used for the analysis, all in the *Net Total Return* version denominated in EUR (which includes the reinvestment of dividends net of withholding taxes):

Table 2.1: Equity indices used in the analysis

Index	Description	Period
MSCI World NET	Global developed markets (23 countries)	2000-2025
MSCI ACWI	Developed + emerging markets	2000-2025
MSCI Europe	European developed markets (15 countries)	2000-2025
MSCI EMU	Eurozone countries (10 countries)	2000-2025

The choice of MSCI (Morgan Stanley Capital International)¹ indices ensures methodological consistency and allows direct comparisons across different geographic areas. Data were downloaded and used at daily frequency for the simulations.

2.2.2 Government bonds

For the bond component, the yields of 10-year government bonds from three Eurozone countries were used:

¹MSCI Inc. is one of the world's leading providers of benchmark equity indices, used as benchmarks by funds and ETFs (*Exchange-Traded Funds*) globally.

Table 2.2: Government bonds used in the analysis

Bond	Country	Source	Period
Bund 10Y	Germany	Bundesbank	2000-2025
BTP 10Y	Italy	Banca d'Italia	2000-2025
OAT 10Y	France	Banque de France	2000-2025 ²

The bond total return was calculated considering both the coupon component (income) and the effect of yield changes on price (duration effect):

$$r_{bond,t} = \frac{y_t}{365} - D \cdot \Delta y_t \quad (2.1)$$

where y_t is the yield to maturity expressed in decimal form, D is the modified duration (approximated at 8 years for 10-year bonds) and Δy_t is the daily yield change. The return is then converted to a log return via $\ln(1 + r_{bond,t})$ to ensure consistency with equity returns and allow correct temporal aggregation.

2.2.3 Inflation

For the inflation adjustment of withdrawals, the HICP (*Harmonised Index of Consumer Prices*) for the euro area, published by Eurostat with base 1996=100, was used. The HICP represents the official measure of inflation in the euro area and ensures comparability across member states.

²OAT (*Obligations Assimilables du Trésor*): French medium- to long-term government bonds. OAT yields were collected but excluded from the final analysis: the Banque de France publishes daily data only from 2004, while for the 2000–2004 period only monthly data are available, introducing an unacceptable methodological heterogeneity.

2.3 Simulation methodology

2.3.1 Block Bootstrap

Unlike traditional Monte Carlo simulations that assume normally distributed and independent returns, this analysis uses the *block bootstrap* technique, introduced by Politis and Romano (Politis and Romano 1994) and applied to financial markets by Cogneau and Zakamouline (Cogneau and Zakamouline 2013). This methodology:

1. Samples consecutive blocks of historical data (rather than individual observations)
2. Preserves the serial autocorrelation of returns
3. Maintains the correlation structure between assets
4. Does not assume any parametric distribution of returns

The block size was set to *6 months*, a compromise between:

- Preserving the persistence of market regimes (bull/bear markets)
- Sufficient variability in the generated sequences

2.3.2 Simulation procedure

For each portfolio scenario, *100,000 independent simulations* were performed. Each simulation follows the following procedure:

1. **Sequence generation:** random concatenation of 6-month blocks (approximately 180 days) of daily returns to cover a 30-year horizon (approximately 10,950 days)

2. **Portfolio return calculation:** for each day t the following formula is applied:

$$r_{portfolio,t} = \ln \left(\sum_i w_i \cdot e^{r_{i,t}} \right) \quad (2.2)$$

where w_i are the asset weights and $r_{i,t}$ are the respective log returns. The formula reflects the fact that log returns, unlike simple returns, are not cross-sectionally additive (i.e. across different assets at the same point in time), but only along the temporal dimension for the same asset. If one were to incorrectly calculate the portfolio return as a weighted average of log returns ($\sum_i w_i \cdot r_{i,t}$), a systematic underestimation would result due to the convexity of the exponential function³. The correct procedure therefore requires converting log returns to growth factors ($e^{r_{i,t}}$), calculating the weighted average of these factors, and finally converting the result back to a log return via the natural logarithm

3. **Continuous rebalancing:** portfolio returns are calculated assuming constant weights, equivalent to daily rebalancing to target weights
4. **Withdrawal calculation:** the annual withdrawal equals the SWR multiplied by the initial portfolio value, adjusted for cumulative inflation:

$$W_t = W_0 \cdot \prod_{i=1}^t (1 + \pi_i) \quad (2.3)$$

where $W_0 = SWR \cdot P_0$ and π_i is the inflation rate of year i (see Section 2.7 for a discussion of the forward-looking bias implicit in this formulation)

³By Jensen's inequality applied to the convex function e^x , we have $\ln(\sum_i w_i \cdot e^{r_i}) \geq \sum_i w_i \cdot r_i$, with equality only in the degenerate case where all returns are identical. As an example, consider a portfolio equally split between two assets with log returns $r_A = +10\%$ and $r_B = -10\%$. The simple weighted average of log returns would incorrectly give 0%, while the correct formula yields $\ln(0,5 \cdot e^{0,10} + 0,5 \cdot e^{-0,10}) \approx 0,50\%$, consistent with the weighted average of simple returns (+10,52% and -9,52%).

5. **Success verification:** the simulation is considered a “success” if the portfolio value remains positive for all 30 years; a “failure” if the portfolio is depleted before then

2.3.3 Simulation parameters

The simulations were conducted by systematically varying the following parameters:

Table 2.3: Simulation parameters

Parameter	Values tested
Withdrawal Rate	3.0%, 3.5%, 4.0%
Equity allocation	60%, 70%, 80%, 90%, 100%
Equity index	MSCI World, ACWI, Europe, EMU, STOXX 600*
Bond	Bund, BTP, Bund+BTP Mix
Time horizon	30 years
Number of simulations	100,000 per scenario
Block size	6 months
Rebalancing	Continuous

* The 5 scenarios with STOXX 600 were excluded from the final analysis as the index is only available in the gross return version (gross dividends), not comparable with the MSCI indices in net return version.

2.4 Evaluation metrics

2.4.1 Success Rate

The primary metric is the success rate, defined as the percentage of simulations in which the portfolio is not depleted over the 30-year horizon:

$$\text{Success Rate} = \frac{\text{Simulations with } P_{30} > 0}{\text{Total simulations}} \times 100 \quad (2.4)$$

A success rate of 95% is generally considered the minimum acceptable threshold, corresponding to 1 failure in every 20 retirees.

With 100,000 simulations per scenario, the standard error of the success rate is on the order of 0.1–0.2 percentage points⁴. This implies that the observed differences between scenarios (for example, 78% vs 65%) are statistically significant and not attributable to sampling variability.

2.4.2 Final value distribution

For all simulations, the final portfolio values are analysed:

- **Median:** central value of the final value distribution
- **Mean:** expected value of the final portfolio
- **5th percentile (P5):** pessimistic scenario
- **95th percentile (P95):** optimistic scenario

2.4.3 Depletion year

For failed simulations, the year in which the portfolio is depleted is recorded. This metric allows assessing the “severity” of failure: depletion at year 28 is less problematic than depletion at year 15.

2.5 Scenarios analysed

A total of *161 distinct scenarios* were analysed. For each of the 4 MSCI indices (World, ACWI, Europe, EMU), 39 scenarios were tested:

⁴For a proportion p , the standard error is $SE = \sqrt{p(1-p)/n}$. The error is maximised for $p = 0,50$ ($SE = 0,16\%$) and decreases for more extreme values of p . For $p = 0,80$, a representative value of the success rates observed in this analysis (which range between 61% and 96%), we obtain $SE \approx 0,13\%$, corresponding to a 95% confidence interval of approximately $\pm 0,25$ percentage points.

- **100% equities:** 3 scenarios (one for each withdrawal rate: 3%, 3.5%, 4%)
- **With Bund:** 4 allocations (60/40, 70/30, 80/20, 90/10) \times 3 WR = 12 scenarios
- **With BTP:** 4 allocations \times 3 WR = 12 scenarios
- **With Bund+BTP Mix:** 4 allocations (60/20/20, 70/15/15, 80/10/10, 90/5/5) \times 3 WR = 12 scenarios

The total for the 4 MSCI indices is therefore $4 \times 39 = 156$ scenarios. To these are added 5 scenarios with the STOXX 600 index (excluded from the final analysis as indicated in Table 2.3), for a total of 161 scenarios.

Each scenario was simulated 100,000 times, for a total of *16.1 million simulations*.

2.6 Tools and implementation

The analysis was implemented in *Python 3.12* using the following libraries:

- **pandas:** data manipulation and analysis
- **numpy:** numerical computations and random number generation
- **joblib:** parallelisation of simulations across multi-core CPUs
- **matplotlib/seaborn:** results visualisation

The simulations were executed in a *Jupyter Notebook* environment to ensure reproducibility and code documentation.

For the parallel execution of 100,000 simulations per scenario, the *joblib* library was used to distribute the computational workload across all available CPU cores. The main challenge in parallel execution is ensuring reproducibility of results: since threads are executed in non-deterministic order, a single global seed is insufficient.

The adopted solution assigns each simulation i a deterministic seed calculated as $seed_i = seed_{base} + i$, where $seed_{base} = 42$. Each simulation therefore creates its own independent random number generator via `np.random.default_rng(seed_i)`. This approach ensures that:

- Results are identical at every execution, regardless of the number of cores used
- The order of simulation completion does not affect results
- Each simulation is statistically independent from the others

2.6.1 Data pipeline

Data processing is organised in a two-stage pipeline, implemented through sequentially numbered Jupyter notebooks:

1. **Preprocessing notebooks** (series 0001–0011): download raw data from original sources (Eurostat, Banca d'Italia, Bundesbank, MSCI), normalise them into a common format, interpolate missing days and calculate daily returns. These notebooks need to be run only once or when updating input data.
2. **Simulation notebooks** (series 0100+): load preprocessed data and run the Monte Carlo simulations. Each notebook corresponds to a specific scenario (combination of equity index, bond, allocation and withdrawal rate).

This separation ensures that data transformations are traceable and that simulations can be re-run quickly without reprocessing the input data.

2.6.2 Reproducibility and containerisation

To ensure full reproducibility of the analysis, the entire execution environment was containerised using *Podman*, a container management platform compatible with Docker that does not require root privileges.

The environment includes:

- Base operating system with Python 3.12
- All Python dependencies with pinned versions
- Jupyter Lab for interactive notebook execution
- Pre-configured input data

To simplify environment setup, the `fire.sh` script was provided, which automates:

1. Container image creation (if not already existing)
2. Container startup with correctly mounted volumes
3. Jupyter Lab exposure on the local port

This approach ensures that anyone can replicate the analysis exactly, regardless of the operating system or local configuration, eliminating the “it works on my machine” problem and ensuring the scientific validity of the results.

The entire source code of the analysis, including Jupyter notebooks, preprocessed data and container configuration, is publicly available on GitHub (Salvati [2025](#)).

2.7 Methodological limitations

It is important to acknowledge the following limitations of the analysis:

1. **Limited historical window:** the 2000–2025 period (25 years) includes significant events (dot-com bubble, 2008 crisis, euro crisis, COVID-19) but may not be representative of all possible future scenarios
2. **Absence of transaction costs:** the simulations do not consider trading commissions, bid-ask spreads⁵ and management costs (TER, *Total Expense Ratio*)⁶ of investment vehicles
3. **“No tax” scenario:** financial income taxation is not considered, which in Italy amounts to 26% for equities and funds, and 12.5% for government bonds
4. **Perfect rebalancing:** it is assumed that rebalancing occurs instantaneously and without costs
5. **Constant withdrawals:** flexible withdrawal strategies that could improve success rates are not considered
6. **Past performance:** past returns do not guarantee future returns; simulations based on historical data implicitly assume that the future will be statistically similar to the past
7. **Forward-looking bias in inflation:** in the implementation, the withdrawal for year t is adjusted using the inflation of year t itself, rather

⁵Bid-ask spread: the difference between the purchase price (ask) and the selling price (bid) of a security; it represents an implicit transaction cost.

⁶TER (*Total Expense Ratio*): a synthetic indicator of the total annual costs of an investment fund, expressed as a percentage of assets under management.

than that of year $t - 1$. Since the withdrawal occurs at the beginning of the year, when that year's inflation is not yet known, this introduces a slight forward-looking bias. The effect is a slight overestimation of success rates, as withdrawals are "correctly" adjusted in advance during periods of high inflation. In a real-world context, the retiree would need to base adjustments on the previous year's inflation or on estimates

Chapter 3

Analysis and results

3.1 Main simulation results

The Monte Carlo simulations conducted across 161 distinct scenarios, for a total of 16.1 million simulations, produced significant results that allow us to answer the research questions posed in Chapter 1.

3.1.1 Success rate with 4% withdrawal rate

Table 3.1 reports the main results for a 4% withdrawal rate, the traditional benchmark in the FIRE literature.

Table 3.1: Success rate and median final value for WR = 4% (60/40 allocation)

Index	Bond	Success Rate	Final Median	Final Mean
MSCI World	Bund	78.35%	899,494 EUR	1,381,636 EUR
MSCI World	BTP	80.46%	1,188,838 EUR	1,848,342 EUR
MSCI World	Mix	79.87%	1,054,239 EUR	1,606,661 EUR
MSCI ACWI	Bund	76.97%	837,272 EUR	1,318,952 EUR
MSCI ACWI	BTP	79.18%	1,113,314 EUR	1,772,350 EUR
MSCI ACWI	Mix	78.53%	983,413 EUR	1,537,335 EUR
MSCI Europe	Bund	65.00%	384,577 EUR	878,249 EUR
MSCI Europe	BTP	67.85%	566,126 EUR	1,227,077 EUR
MSCI Europe	Mix	66.80%	482,433 EUR	1,045,166 EUR
MSCI EMU	Bund	60.88%	294,456 EUR	891,975 EUR
MSCI EMU	BTP	63.57%	442,670 EUR	1,250,384 EUR
MSCI EMU	Mix	62.52%	375,056 EUR	1,063,453 EUR

The most relevant finding is that *the 4% rule does not reach the 95% safety threshold in any of the European scenarios tested*. The best result (80.46%) is obtained with MSCI World + BTP, while purely European indices (MSCI Europe, MSCI EMU) show significantly lower success rates, between 61% and 68%.

The subsequent tables in this chapter, up to Section 3.3, use the German Bund as the reference bond component, as it is the core euro area government bond with the lowest credit risk. The detailed comparison with Italian BTPs and mixed portfolios is analysed in Section 3.3.

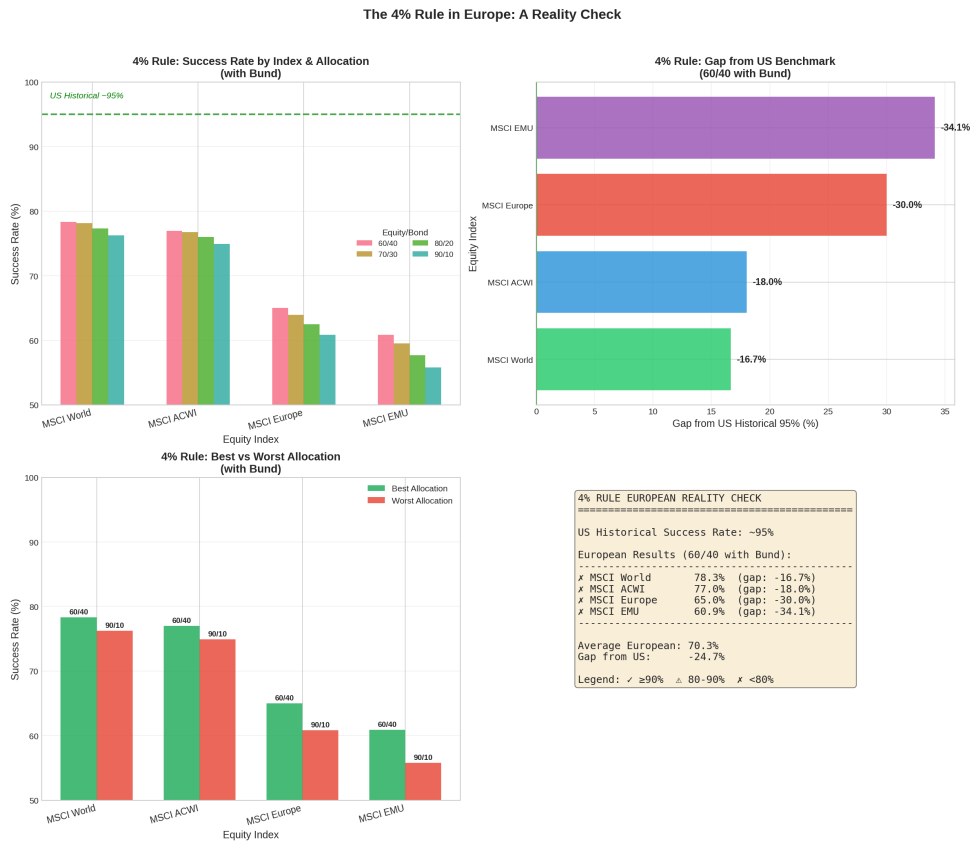


Figure 3.1: The 4% rule in Europe: a reality check

3.1.2 Comparison across withdrawal rates

Table 3.2 shows the impact of the withdrawal rate on the success rate for the MSCI World + Bund 60/40 portfolio.

Table 3.2: Impact of withdrawal rate on success rate (MSCI World + Bund 60/40)

WR	Success Rate	Final Median	Failures
3.0%	95.82%	1,850,878 EUR	4,178
3.5%	89.08%	1,371,863 EUR	10,924
4.0%	78.35%	899,494 EUR	21,647

Only with a 3% withdrawal rate and a globally diversified portfolio is the 95% safety threshold reached. This result, however, is not universal: as shown in Table 3.3, only MSCI World (95.82%) and MSCI ACWI (95.30%) exceed the 95% threshold at 3%, while purely European indices remain significantly below: MSCI Europe stops at 90.13% and MSCI EMU at 86.20%. A 3.5% WR represents an acceptable compromise for global portfolios, with approximately 89% probability of success.

Table 3.3: Success rate by equity index and withdrawal rate (60/40 allocation, Bund)

Index	WR 3.0%	WR 3.5%	WR 4.0%
MSCI World	95.82%	89.08%	78.35%
MSCI ACWI	95.30%	88.10%	76.97%
MSCI Europe	90.13%	79.16%	65.00%
MSCI EMU	86.20%	74.67%	60.88%

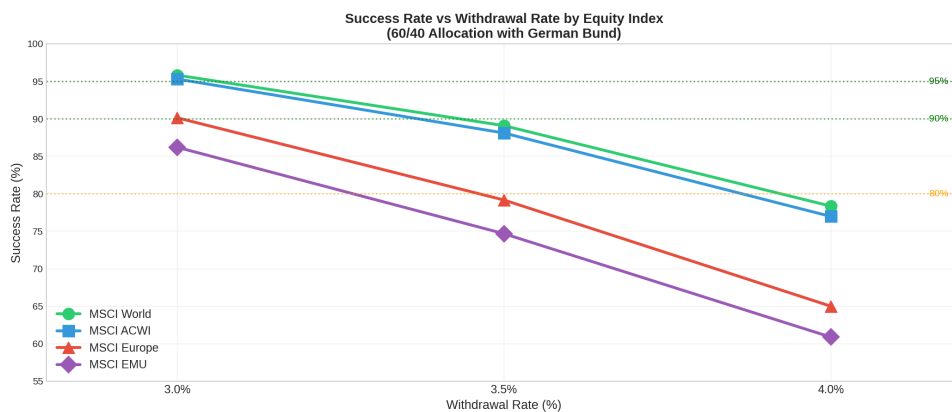


Figure 3.2: Success rate as a function of withdrawal rate for all indices

3.2 Impact of geographic diversification

One of the most significant findings of the analysis concerns the impact of geographic diversification on the sustainability of the withdrawal plan.

3.2.1 Comparison across equity indices

Table 3.4: Success rate by equity index (WR = 4%, Bond = Bund, 60/40)

Index	Success Rate	Delta vs World	Failures
MSCI World	78.35%	—	21,647
MSCI ACWI	76.97%	-1.38 pp	23,034
MSCI Europe	65.00%	-13.35 pp	34,999
MSCI EMU	60.88%	-17.47 pp	39,123

The difference between MSCI World and MSCI EMU is *17.5 percentage points*: this means that an investor who chooses to invest only in the Eurozone has almost double the probability of depleting the portfolio compared to one who diversifies globally.

This result confirms the importance of geographic diversification and warns against home bias, i.e. the tendency of investors to overweight domestic markets. Figure 3.3 shows how the gap between global and European portfolios is consistent at all withdrawal rate levels: +7.4 percentage points at 3%, +11.7 pp at 3.5% and +14.7 pp at 4%.

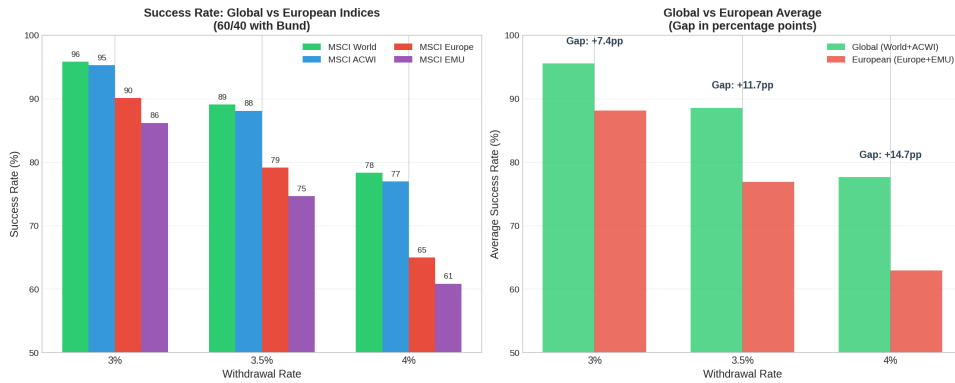


Figure 3.3: Comparison between global and European indices: the diversification gap

3.2.2 Impact of equity allocation

Table 3.5: Success rate by equity allocation (MSCI World + Bund, WR = 4%)

Allocation	Success Rate	Final Median	Final P95
60/40	78.35%	899,494 EUR	4,541,365 EUR
70/30	78.17%	1,097,975 EUR	6,181,313 EUR
80/20	77.33%	1,282,788 EUR	8,270,551 EUR
90/10	76.23%	1,444,403 EUR	10,825,881 EUR
100/0	74.86%	1,580,517 EUR	14,008,419 EUR

Contrary to what one might intuit, *more aggressive allocations do not improve the success rate*. The 60/40 allocation achieves the best result, while the 100% equity portfolio has the lowest success rate (74.86%). This is explained by the greater volatility of the equity portfolio, which amplifies the sequence of returns risk. As highlighted by Kitces and Pfau (Kitces and Pfau 2015), the sequence of returns in the early years of retirement is decisive for the long-term success of the withdrawal plan.

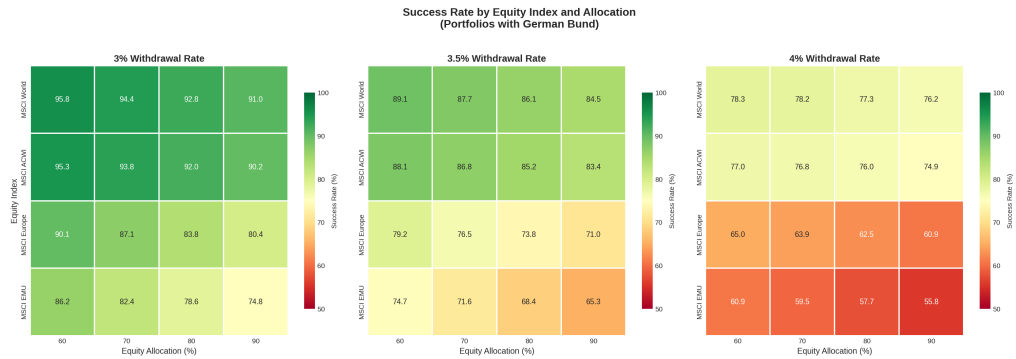


Figure 3.4: Success rate by index and allocation at different withdrawal rates

3.3 Comparison across bond types

A distinctive aspect of the analysis concerns the choice of bond component for a euro area investor.

3.3.1 Bund vs BTP

Table 3.6: Success rate by bond type (MSCI World, WR = 4%, 60/40)

Bond	Success Rate	Delta vs Bund	Final Median
Bund 10Y	78.35%	—	899,494 EUR
BTP 10Y	80.46%	+2.11 pp	1,188,838 EUR
Bund+BTP Mix	79.87%	+1.52 pp	1,054,239 EUR

Surprisingly, *Italian BTPs outperformed German Bunds* over the analysed period, with a 2.1 percentage point advantage in success rate and a 32% higher median final value.

This result is explained by the historically higher yields of BTPs compared to Bunds, which more than compensated for the greater per-

ceived credit risk. However, it is important to note that this result is specific to the 2000–2025 period and may not be repeated in the future, especially in scenarios of Italian sovereign debt crisis.

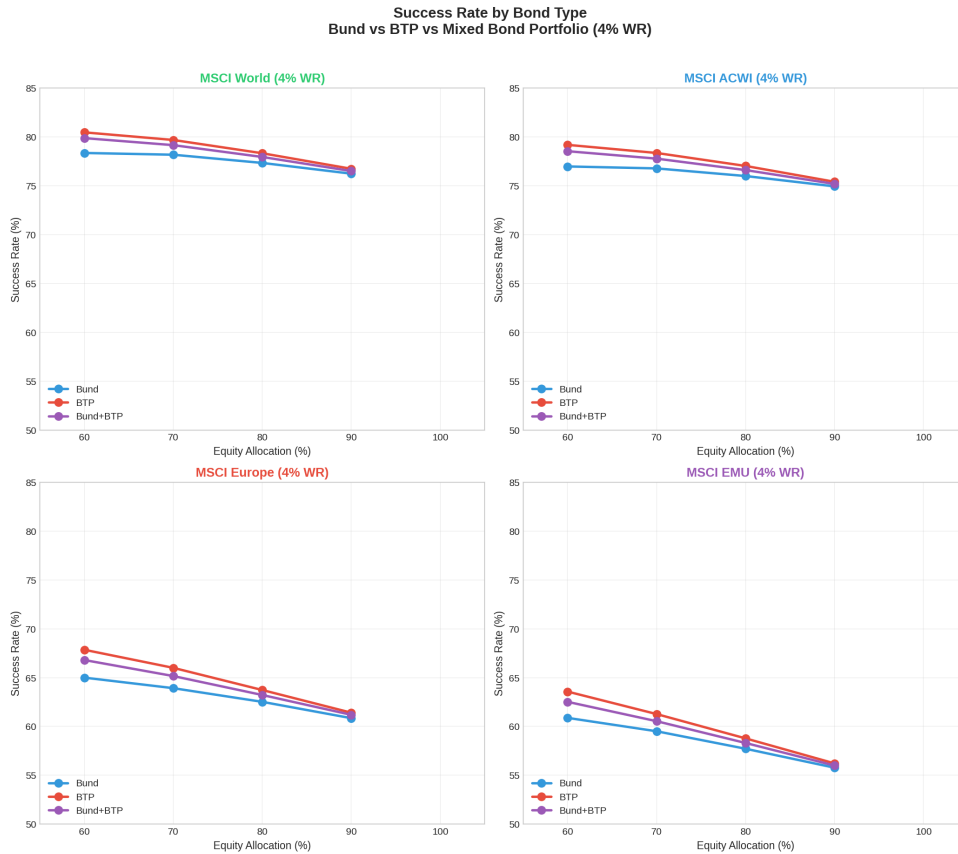


Figure 3.5: Success rate by bond type and equity index

3.4 Failure analysis

3.4.1 Portfolio depletion year

For simulations that end with portfolio depletion, it is important to analyse when the failure occurs.

Table 3.7: Depletion year for failed portfolios (MSCI World + Bund 60/40)

WR	Median	Mean	Minimum
3.0%	Year 27	Year 26.7	Year 14
3.5%	Year 27	Year 26.1	Year 13
4.0%	Year 26	Year 25.3	Year 12

Most failures occur in the final years of the 30-year horizon. However, in the worst cases, the portfolio can be depleted after just 12 years, highlighting the importance of the sequence of returns risk. Estrada (Estrada 2017; Estrada 2018) has proposed alternative metrics to the success rate, such as shortfall years, which measure how many years before the end of the horizon a portfolio is depleted: a failure at year 28 is very different from one at year 15.

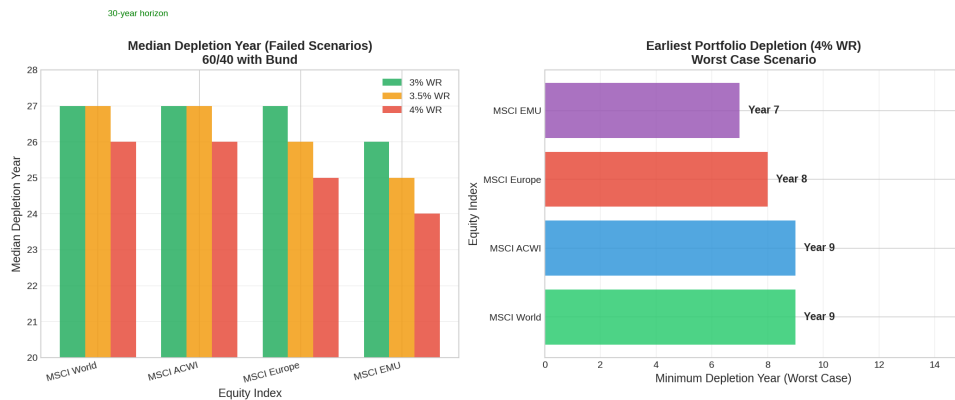


Figure 3.6: Depletion year analysis for failed portfolios

3.4.2 Final value distribution

The final value distribution is strongly skewed: while the median is approximately 900,000 EUR with a 4% WR, the best 5% of simulations end

with over 4.5 million EUR. This indicates that, in favourable cases, the portfolio not only survives but grows significantly. Conversely, with a 3% WR the median final value rises to approximately 1.85 million EUR, highlighting the trade-off between safety and spending capacity.

3.5 Summary of results for a European investor

3.5.1 Optimal scenario

Based on the analysis results, the optimal scenario for a European investor pursuing FIRE is:

Table 3.8: Optimal scenarios for a European investor

Profile	Configuration	WR	Success Rate
Conservative	MSCI World + Bund/BTP Mix 60/20/20	3.0%	95.91%
Conservative	MSCI ACWI + Bund/BTP Mix 60/20/20	3.0%	95.39%
Moderate	MSCI World + Bund/BTP Mix 60/20/20	3.5%	89.74%
Moderate	MSCI ACWI + Bund/BTP Mix 60/20/20	3.5%	88.81%
Aggressive	MSCI World + Bund/BTP Mix 60/20/20	4.0%	79.87%
Aggressive	MSCI ACWI + Bund/BTP Mix 60/20/20	4.0%	78.53%

3.5.2 Implications for the FIRE number

The “FIRE number” varies significantly based on the chosen withdrawal rate:

Table 3.9: FIRE number for different annual expenses

Annual expenses	WR 3%	WR 3.5%	WR 4%
20,000 EUR	666,667 EUR	571,429 EUR	500,000 EUR
25,000 EUR	833,333 EUR	714,286 EUR	625,000 EUR
30,000 EUR	1,000,000 EUR	857,143 EUR	750,000 EUR
35,000 EUR	1,166,667 EUR	1,000,000 EUR	875,000 EUR
40,000 EUR	1,333,333 EUR	1,142,857 EUR	1,000,000 EUR

For an investor with annual expenses of 30,000 EUR:

- With 3% WR (conservative): 1,000,000 EUR required
- With 4% WR (aggressive): 750,000 EUR required

The 250,000 EUR difference represents the “safety premium” for moving from 80% to 95% probability of success.

3.6 Decision matrix

Figure 3.7 provides a decision matrix for the European investor, summarising the success rates for the main combinations of equity index and withdrawal rate, comparing the 60/40 allocation with Bund only and the 60/20/20 allocation with Bund/BTP mix.

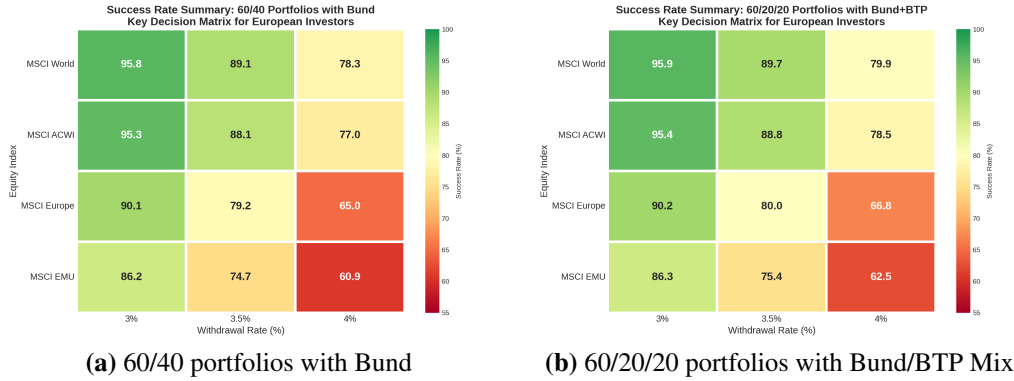


Figure 3.7: Decision matrix: success rate by index and withdrawal rate

3.7 Risk-return trade-off

The choice of withdrawal rate entails a fundamental trade-off between safety and spending capacity. A 3% WR guarantees maximum safety (over 95% for global portfolios) but requires an initial capital 33% higher than the 4% WR. Conversely, a 4% WR allows reaching FIRE with lower capital, but exposes one to a significantly higher failure risk (approximately 20–40% depending on the chosen index).

3.8 Comparative summary

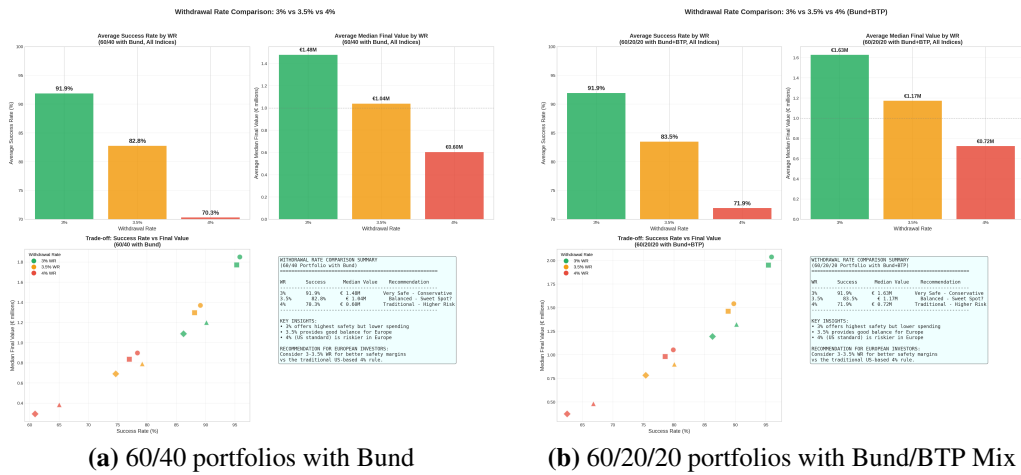


Figure 3.8: Comparative summary of withdrawal rates

In summary, the analysis results indicate that:

1. The 4% rule is not safe in the European context, with success rates between 61% and 80% depending on the configuration, far from the 95% historical US benchmark
2. The safe 3% WR applies only to globally diversified portfolios (MSCI World: 95.82–95.91%, MSCI ACWI: 95.30–95.39% depending on the bond component); purely European indices never reach 95%, even with a 3% WR (MSCI Europe: 90.13%, MSCI EMU: 86.20%)
3. Global diversification is fundamental: the gap between global and European portfolios is consistent at all WR levels (+7.4 pp at 3%, +11.7 pp at 3.5%, +14.7 pp at 4%)

4. For a European investor, *peripheral bonds (BTP) outperformed core bonds (Bund)* over the analysed period, offering an approximately 2 percentage point advantage in success rate, albeit with higher credit risk; for this reason, a *Bund/BTP mix appears preferable* to diversify sovereign risk

5. The *optimal allocation is 60/40 or 70/30*, with more aggressive allocations not improving the success rate but increasing volatility

Chapter 4

Conclusions and perspectives

4.1 Summary of results

This thesis has analysed the applicability of the 4% rule and FIRE strategies to the European and Italian context through Monte Carlo simulations across 161 distinct scenarios, for a total of 16.1 million simulations. The main results can be summarised as follows:

1. **Applicability of the 4% rule:** the 4% rule, developed in the US context, does not guarantee an adequate level of safety in the European context. The maximum success rate obtained is 80.46% (MSCI World + BTP 60/40), well below the 95% threshold considered acceptable in the literature.
2. **Safe Withdrawal Rate for Europe:** a 3% withdrawal rate is necessary to achieve a success rate above 95%, but *only with a globally diversified portfolio* (MSCI World: 95.82–95.91%, MSCI ACWI: 95.30–95.39% depending on the bond component). Purely European indices never reach this threshold, even at 3% (MSCI Europe: 90.13–90.20%, MSCI EMU: 86.20–86.26%). A 3.5% rate represents a reasonable compromise for global portfolios, with approximately 89% probability of success.

3. **Importance of global diversification:** investing exclusively in European markets (MSCI Europe or MSCI EMU) reduces the success rate by 13–17 percentage points compared to a globally diversified portfolio (MSCI World).
4. **Optimal asset allocation:** the 60/40 allocation (60% equities, 40% bonds) is optimal in terms of success rate, with more aggressive allocations increasing volatility without improving the probability of success.
5. **Bond component choice:** over the analysed period (2000–2025), Italian BTPs offered an approximately 2 percentage point advantage over German Bunds, thanks to higher yields that compensated for the greater credit risk; however, a Bund/BTP mix appears preferable to diversify sovereign risk.

4.2 Answers to the research questions

4.2.1 Is the 4% rule applicable to the European and Italian context?

No, the 4% rule is not directly applicable to the European context. The simulations show that with a 4% withdrawal rate, the success rate varies between 61% and 80% depending on the portfolio configuration, significantly below the 95% originally observed in US studies.

This result is consistent with the international studies by Wade Pfau (Pfau 2010; Pfau 2012) and with the analysis by Blanchett, Finke and Pfau (Blanchett, Finke, and Pfau 2013) on the low bond yield environment. The main causes are:

- Lower historical returns of European equity markets compared to US markets

- Greater volatility and impact of crises (dot-com, 2008, sovereign debt crisis, COVID-19)
- Lower bond yields, especially in the post-2008 period

4.2.2 What Safe Withdrawal Rate is appropriate for a European investor?

For a European investor who desires a high level of safety (success rate $\geq 95\%$), *the analysis indicates that a 3% withdrawal rate is necessary, provided the equity portfolio is globally diversified (MSCI World or ACWI)*. This corresponds to a multiplier of 33x annual expenses (rather than the traditional 25x of the 4% rule).

It is crucial to emphasise that the 95% threshold is not achievable with purely European portfolios: MSCI Europe stops at 90.13–90.20% and MSCI EMU at 86.20–86.26% (depending on the bond component), even with a 3% WR.

For investors willing to accept greater risk, 3.5% (success rate $\approx 89\%$ with global portfolios) represents a reasonable compromise, corresponding to a multiplier of approximately 29x.

4.2.3 How does geographic diversification impact results?

Geographic diversification is *fundamental*. With a 4% WR, the success rate progressively declines moving from global indices (MSCI World 78.35%, ACWI 76.97%) to European indices (MSCI Europe 65.00%) to the Eurozone (MSCI EMU 60.88%).

This result highlights the risks of home bias and underscores the importance of building a globally diversified portfolio, ideally through index-tracking instruments that replicate global indices. As documented

by Cremers et al. (Cremers et al. 2016), passive investing through ETFs represents an efficient and cost-effective strategy.

4.2.4 Which asset allocation strategies are most suitable?

The *60% equities / 40% bonds* allocation is optimal for maximising the success rate. Contrary to intuition, more aggressive portfolios (80/20 or 100/0) do not improve the probability of success; indeed, they slightly worsen it due to greater exposure to sequence of returns risk.

For a European investor, the optimal combination is:

- **Equity component:** MSCI World (or MSCI ACWI to include emerging markets)
- **Bond component:** Bund/BTP mix (to diversify sovereign risk)
- **Allocation:** 60/40 or 70/30
- **Rebalancing:** periodic (annual or semi-annual)

4.2.5 What are the key success factors for FIRE in Italy?

The key factors emerging from the analysis are:

1. **Conservative withdrawal rate:** using 3–3.5% rather than 4%
2. **Global diversification:** avoiding European home bias
3. **Balanced allocation:** maintaining a significant bond component (30–40%)
4. **Safety margin:** accumulating capital above the theoretical minimum
5. **Flexibility:** being willing to reduce expenses in unfavourable market conditions

4.3 Contributions of the thesis

This thesis offers the following contributions:

- **Theoretical contribution:** extension of the Safe Withdrawal Rate literature to the European context, with particular attention to the Italian case. Empirical confirmation that the 4% rule is not universally applicable.
- **Practical contribution:** analysis of the implications for European investors pursuing financial independence, with empirical evidence on withdrawal rates, asset allocation and geographic diversification.
- **Methodological contribution:** application of the block bootstrap technique (Efron and Tibshirani 1993; Politis and Romano 1994) for Monte Carlo simulations, which preserves temporal correlations in returns and does not assume parametric distributions.

4.4 Practical implications

Note: the considerations that follow derive exclusively from the analysis of historical data and the simulations presented in this thesis. They do not constitute personalised financial advice and should not be interpreted as such. Every investment decision should be made with the support of a licensed financial adviser, based on one's personal circumstances.

4.4.1 Considerations for European investors

Based on the analysis results, the following considerations emerge for those intending to pursue financial independence in Europe:

1. **Withdrawal rate:** the analysis suggests that a 3% rate (33x multiplier) offers greater safety than the traditional 4% (25x multiplier). For expenses of 30,000 EUR/year, this implies capital of 1,000,000 EUR rather than 750,000 EUR.
2. **Global diversification:** the results highlight the importance of including extra-European markets in the equity portfolio (global indices such as MSCI World or ACWI). As argued by Bogle (Bogle 2007) and Malkiel (Malkiel 2019), low-cost index investing represents an efficient strategy for most investors.
3. **Bond component:** the simulations indicate that a 30–40% allocation to government bonds (Italian BTPs or a mix with Bunds, preferable for diversifying sovereign risk) contributes to reducing portfolio volatility.
4. **Safety margins:** factors not included in the analysis (taxation, transaction costs, unexpected healthcare expenses) suggest the appropriateness of considering capital above the theoretical minimum.
5. **Withdrawal flexibility:** the literature (Guyton 2004; Guyton and Klinger 2006) indicates that the willingness to temporarily reduce expenses during sharp market downturns, especially in the early years of retirement, can significantly improve the probability of success.

4.4.2 Implications for financial advisory

The analysis results may be relevant for financial advisers assisting clients interested in FIRE:

- The differences between the US and European contexts are significant and warrant attention

- The use of more conservative withdrawal rates (3–3.5%) in projections appears justified by the data
- Geographic diversification emerges as a determining factor for success rates
- Flexible withdrawal plans that adapt to market conditions can improve the probability of success
- The integration of FIRE planning with public and supplementary pensions represents an aspect worth considering

4.5 Study limitations

It is important to acknowledge the following limitations of this study:

1. **Limited historical window:** the 2000–2025 period (25 years) may not be representative of all possible future scenarios. It includes significant events but does not capture, for example, periods of prolonged high inflation.
2. **Absence of taxation:** the simulations were conducted in a “no tax” scenario. The impact of Italian taxation (26% on equity capital gains, 12.5% on government bonds) would further reduce net returns and the sustainable SWR.
3. **Costs not considered:** transaction costs, bid-ask spreads, management costs (TER) of investment vehicles and stamp duty are not included.
4. **Daily rebalancing:** the simulations assume daily portfolio rebalancing, while in practice investors typically rebalance annually or semi-

annually. Frequent rebalancing keeps the portfolio closer to the target allocation, which could lead to a slight overestimation of success rates.

5. **Rigid withdrawals:** the analysis assumes fixed withdrawals adjusted for inflation. Dynamic withdrawal strategies such as those proposed by Guyton and Klinger (Guyton 2004; Guyton and Klinger 2006) or analytical approaches such as those of Milevsky and Robinson (Milevsky and Robinson 2005) could improve success rates.
6. **Absence of supplementary income:** the possibility of part-time income or additional revenue during retirement is not considered. In particular, the European public pension system (OECD 2021), once the statutory retirement age is reached, could supplement portfolio income and allow a lower withdrawal rate.
7. **Implicit currency risk:** global indices (MSCI World, ACWI) have high exposure to the US dollar ($\approx 60\text{--}70\%$). Although the data used are denominated in euros, EUR/USD exchange rate fluctuations are embedded in the returns and could influence results in future scenarios with different currency dynamics.

4.6 Perspectives and future developments

4.6.1 Possible research developments

This work paves the way for several possible future research directions:

1. **Inclusion of taxation:** developing models that incorporate the different European tax regimes and their respective pension-related tax advantages.

2. **Dynamic withdrawal strategies:** analysing the impact of flexible withdrawal strategies such as Guyton-Klinger, Variable Percentage Withdrawal (VPW) or floor-and-ceiling approaches.
3. **Integration with public pensions:** modelling the interaction between private savings and European public pension systems.
4. **Longer time horizons:** extending the analysis to 40 or 50 years for those aspiring to very early retirement.
5. **Sensitivity analysis on future scenarios:** testing the robustness of results under different assumptions about future returns (prolonged low-rate scenario, high inflation, etc.).
6. **Inclusion of alternative assets:** evaluating the impact of including real estate, commodities or cryptocurrencies in the portfolio.

4.6.2 Evolution of the regulatory and market environment

The environment in which European investors operate is constantly evolving. Some developments to monitor include:

- Possible changes to financial income taxation
- Evolution of the public pension system and statutory retirement age
- Development of new tax-advantaged savings instruments
- Impact of climate change on long-term returns
- Demographic trends and their effects on pension system sustainability

4.7 Final considerations

The FIRE movement represents a concrete response to the challenges posed by the transformation of pension systems and the desire for greater control over one's working and financial life. However, the uncritical application of rules developed in the US context can lead to underestimating risks in the European context.

This thesis has demonstrated that the 4% rule, while being a useful reference point, requires significant adjustments to be applied in Europe. The analysis results highlight several key elements for the European context:

- A more conservative approach (3–3.5% withdrawal rate) appears necessary to achieve high success rates
- Global diversification of the equity portfolio proves decisive
- A significant bond component contributes to portfolio stability
- Safety margins and spending flexibility can mitigate risks

FIRE is not a goal achievable by everyone, but with careful planning, a high savings rate and informed investment choices, it can represent a realistic objective for those willing to make the necessary sacrifices during the accumulation phase.

Retirement savings management requires a rigorous, data-driven and risk-aware approach. This thesis has sought to contribute in this direction, offering an empirical analysis to better understand the dynamics of the Safe Withdrawal Rate in the European and Italian context.

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