Winner Bias and the Equity Premium Puzzle

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Abstract

The equity premium puzzle in US stocks can be resolved by winner bias. This bias equals the difference between an expected ex-post equity premium conditioned on being the sample maximum (the "winner") and its ex-ante premium. After correcting for winner bias, the observed US equity premium is consistent with an ex-ante premium of zero. A simple model is used where the return on every global market has equal mean and variance, and equal ex-ante equity premium of zero. The expected winner's ex-post equity premium is 6.1% and the Sharpe ratio is 32%. These values match the historical US premium of 6.2% and Sharpe ratio 37%, and are not statistically different. This implies that the ex-ante US equity premium is substantially lower than observed.

Key words: Equity premium, selection bias

JEL Classification: G10, G12, G15

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1 Introduction

There is a tendency to study the "best" or "winner" observation more than any other in a sample. The most successful CEOs, wealthiest individuals, most profitable businesses and best performing stock markets attract more attention and academic study than the mediocre and the failed. If such success is due to chance, historical performance of the winner will overestimate the expected ex-ante performance and expected future performance. The effect, termed "winner bias," affects estimates of US stock market performance and is sufficient to resolve the equity premium puzzle.

The US stock market was the most successful market in the 20th century. The market realized an average excess-return, or equity premium, of approximately 5% per annum over 75 years. The market size grew from 16% of total market capitalization in 1900 to 53% in 2000; and since then remains the worlds' largest market. Perhaps due to its success, the US market is also the most analyzed and examined financial market in history. The US is evidently the "winner" among global stock markets.

In contrast, there were many countries with poor long-term equity performance in the 20th century. Due to war, revolution or financial crisis, these countries have realized negative equity premia. Some examples include: Belgium (-0.3%), Spain (-1.8%), India (-2.3%), Argentina (-4.8%), and over long horizons, Russia (-100%) and China (-100%) (Jorion and Goetzmann, 1999). Partly as a consequence of their unimpressive performance, these countries contribute a small percentage to total market capitalization. There are relatively few studies of these countries compared to those of the United States¹.

The equity premium puzzle (Mehr and Prescott, 1985) is the apparent contradiction between the estimated equity premium of the US market (ranging between 4-7%) and the predicted equity premium from the standard consumption-based asset-pricing model (0-2%), assuming reasonable levels of risk-aversion. The difference can be resolved by assuming implausibly high levels of investor risk aversion. However, this consequently produces a second contradiction, the "risk-free rate puzzle" (Weil, 1989), where the implied risk-free rate is also implausibly high.

Either the standard consumption asset pricing model is misspecified, or estimates of the historical US equity premium much higher than the actual premium. The puzzle has attracted considerable academic debate, and and there are numerous proposed "solutions" to the puzzle; see Kocherlakota (1996) and Cochrane (2000) for overviews.

¹The number of studies according to country was measured using articles from the *Journal of Finance* over 1946 to 2004. In a sample of 8188 articles, the term "United States" appears in 4350 articles, "Canada" in 861, "Japan" in 548, "Germany" in 470, "France" in 463, "India" in 301, "Mexico" in 271, "Australia" in 235, "China" in 117, and "Argentina" in 82. There appears to be a substantial US bias in empirical study.

Despite these proposals, Mehr and Prescott (2006) argue that the puzzle remains unsolved.

The particular focus on explaining the US equity premium, as opposed to other countries' premia, indicates a bias in the literature. Asset pricing models, and their predictions such as the expected equity premium, should apply to *all* markets and not just those in the United States. Yet there are very few studies looking whether the puzzle exists elsewhere². Given that the US is the "winner", it immediately follows that the observed equity premium in all other countries is lower.

This paper argues that *there is no puzzle*: the estimated US equity premium is positivelybiased due to winner bias. The condition that the US was the 20th century "winner" automatically implies that its expected ex-post equity premium is higher than its actual ex-ante equity premium. Formally, this is the statement

$$E[R_1|R_1 = \max(R_1, R_2, ..., R_N)] > E[R_1]$$

where R_1 is the realized US equity premium, $R_2, ..., R_N$ are other countries' realized premia, $E[R_1]$ is the ex-ante US equity premium and $E[R_1|\cdot]$ is the expected realization of the US equity premium conditioned on the the US being the ex-post winner. If the actual US premium is lower than estimated, both the equity premium puzzle and the risk-free rate puzzle are partially resolved; and if the premium is sufficiently low, both are fully resolved. The challenge is therefore in quantifying the winner bias.

Winner bias is quantified using the simplest possible model for global equity returns. There are several hypothetical countries where each country's return on equity is independent and normally distributed, and each has an ex-ante equity premium of zero. There is no pre-supposed superiority of one country, and each has equal probability of achieving the maximum ex-post equity premium. Parameters in the model are set to averages from the Jorion and Goetzmann (1999) study of 39 global stock markets. The model is highly parsimonious, involves few parameters, and yields strong testable predictions about the distribution of equity premia and market capitalizations.

The observed US equity premium and Sharpe ratio are not statistically different from the expected maximum equity premium and Sharpe ratio in the model. Assuming 40 hypothetical countries and 50 years of observed returns, the expected maximum equity premium is 6.1% and maximum Sharpe ratio is 32%. These results match the Mehr and Prescott (1985) reported US premium of 6.2% and Sharpe ratio of 37%, and are not statistically different. This implies that the observed US equity premium can be entirely attributed to winner bias and that its performance is consistent with a zero equity premium.

²Jorion and Goetzmann, 1999 and Dimson, Marsh and Staunton, 2006 are notable exceptions, and estimate lower equity premia in other countries.

Further tests of the model are conducted. The model predicts the distribution of realized equity premia across countries. Historical returns from 38 countries are used to test the model, and results are affirmative: there is no significant difference between the sample of observed equity premia and the distribution predicted by the model. The model also predicts the distribution of market capitalizations across countries. The expected maximum percentage market capitalization in the model is 29% which compares favorably to the the current US percentage capitalization of 30%. The distribution of percentage capitalizations implied by the model is tested against the distribution of country capitalizations. No significant difference exists between the two distributions.

These three findings imply that the simple model is sufficient to explain variations in equity market successes and failures experienced by countries. The model may appear over-simplistic, and I consider two extensions: where the mean and/or variance of country returns is stochastic, and when the returns across countries are correlated. I show that the observed maximum equity premium and Sharpe ratio from such models are greater than from the simple model. This implies that the predictions from the simple model are in fact conservative, and that winner bias may play an even greater role than estimated.

A related model was presented by Brown, Goetzmann & Ross (1995). They argue that ex-post premia are positively biased due to the non-survival of some markets. Li and Xu (1999) and Dimson, Marsh and Staunton (2006) dismiss survivorship as an adequate explanation to the equity premium puzzle. Both show that unrealistically high probabilities of market extinction are required to fit the observed US premium. Dimson, Marsh and Staunton (2006) estimate the size of survivorship bias as 0.1% of the observed equity premium.

2 The Model

The simplest possible model is constructed for the long term performance of global stock markets. There are N hypothetical countries and T years of observed annual returns. In each country, the excess return over the risk-free rate is: normally distributed, serially independent, identically distributed and independent of other countries. Furthermore, each country has the same mean and variance.

This last assumption implies that there is nothing special about the performance of any country except inasmuch as their realized returns differ. Ex-post, some countries will appear to have higher expected returns by luck alone.

Let $R_{i,t}$ denote the excess return for country *i*. The model is formally specified as

 $R_{i,t} \sim \text{i.i.d } \mathcal{N}(\mu, \sigma^2)$ for all countries.

The ex-ante equity premium across all countries is μ and the Sharpe ratio is $\frac{\mu}{\sigma}$.

I assume that $\mu = 0$. Each country has an equity premium and Sharpe ratio equal to zero. There is no equity-premium puzzle in any country, nor is there a risk-free rate puzzle. After observing T years of returns, however, there will *appear* to be equity premium puzzles in some lucky countries due to sampling variation.

The free parameters in the model are σ^2 , N and T. These are set to equally-weighted averages in the Jorion and Goetzmann (1999) data-set of 39 countries: $\sigma^2 = 0.2$ (sample average is 23%). T = 50 (sample average is 53 years; this also corresponds to the post-World War II period);. The number of hypothetical countries with stock-markets is set to $N = 40.^3$

The model is the simplest that might be proposed to explain the equity premium puzzle. It does not assume non-survival of some countries' markets (Brown, Goetzmann and Ross, 1995) or small probabilities of financial disaster (Rietz, 1988; Barro, 2005). It does not require consumption habits (Constantinides, 1990; Campbell and Cochrane, 1999), incomplete markets (Weil, 1992), heterogeneous agents (Constantinides and Duffie, 1996) or Bayesian learning (Weitzman, 2005).

The model's parsimony is important: all other explanations of the equity premium puzzle involve more modeling components and more parameters, which makes fitting theoretical predictions to the observed US premium easier. With explanatory power being equal, the parsimonious model is likely to be more plausible than alternative, more complex models. The model does not resort to finely tuning parameters⁴, or involve reverse engineering⁵.

The model also has more explanatory power than past proposed solutions. It explains the US equity premium, the global variation of observed equity premia, and the variation of global market capitalizations. Past proposal models calibrated to and tested against *one* observation (the US equity premium). The model here is tested against many observations (38 equity premia, 30 market capitalizations).

 $^{^{3}}$ There are currently 67 stock markets that US investors can participate in using index funds (MSCI-Barra, 2008). The MSCI-Barra World Index uses 48 countries, which includes 23 "developed" and 25 "developing" markets but excludes 19 "frontier" markets. I assume 40 countries since several of the developing markets and nearly all the frontier markets have not existed longer than the considered 50 years period.

⁴See Mehr and Prescott's (1988) criticism of Rietz's (1988) disaster model; Li and Xu's criticism of the Brown, Goetzmann and Ross (1995) survival model.

⁵Cochrane (1999) on the Cochrane and Campbell (1999) model: "the Campbell-Cochrane model is blatantly (and proudly) reverse engineered..."

3 Quantifying Winner Bias

Winner bias is the difference between the expectation of a random variable that is conditioned on being the ex-post maximum in a sample and its unconditional expectation:

Winner Bias =
$$E[R_1|R_1 = \max(R_1, R_2, ..., R_N)] - E[R_1].$$

The bias is positive regardless of the distribution of $R_1, ..., R_N$. In particular, the bias is positive even if R_1 has a higher unconditional expectation than $R_2..., R_N$. The model in section 2 assumes that R_j have identical distributions; each country has equal chance of being the ex-post winner. This assumption simplifies the expression to

$$E[R_1|R_1 = \max(R_1, R_2, ..., R_N)] - E[R_1] = E[\max(R_1, ..., R_N)] - \mu.$$

The quantities of interest are the ex-post equity premium and Sharpe ratio. Let the annual excess-returns for N countries be denoted $\{R_{1,t}, R_{2,t}, ..., R_{N,t}\}_{t=1}^{T}$ over T years. Throughout the paper, returns are assumed to be geometric (logarithmic) and not arithmetic. The estimate for the equity premium for country *i* over T years is

$$\overline{R}_i = \frac{1}{T} \sum_{t=1}^T R_{i,t}$$

The estimate of the Sharpe ratio for country i is

$$\overline{SR}_{i} = \frac{\frac{1}{T} \sum_{t=1}^{T} R_{j,t}}{(\frac{1}{T-1} \sum_{t=1}^{T} (R_{j,t} - \overline{R}_{j})^{2})^{1/2}} = \frac{\overline{R}_{i}}{S_{i}}.$$

The following results provide expressions for the expected ex-post winner's equity premia and Sharpe ratio.

Result 1 (Equity Premium): The expected winner's ex-post equity premium is approximately

$$E[\max(\overline{R}_1, ..., \overline{R}_N)] \doteq \mu + \frac{\sigma}{\sqrt{T}} \mathcal{QN}\left(\frac{N-\alpha}{N-2\alpha+1}\right)$$
(1)

where QN is the quantile function of the standard normal distribution and α is a constant approximately equal to 0.37 (this value is discussed in section A of the appendix). $\mu = 0$ in the model, and therefore this is also the expression for the winner's bias. If returns are ordered into an ascending sequence, the K^{th} order return $\overline{R}^{(K)}$ has expectation

$$E[\overline{R}^{(K)}] \doteq \mu + \frac{\sigma}{\sqrt{T}} \mathcal{QN}\left(\frac{K-\alpha}{K-2\alpha+1}\right).$$

Result 2 (Sharpe Ratio): The expected maximum Sharpe ratio over N countries is

$$E[\max(\overline{SR}_1, ..., \overline{SR}_N)] \doteq \frac{\mu}{\sigma} + \frac{1}{\sqrt{T}} \mathcal{QT}_{T-1} \left(\frac{N-\alpha}{N-2\alpha+1}\right)$$
(2)

where QT_{T-1} is the quantile function for the Student's-t distribution with T-1 degrees of freedom.

The K^{th} order Sharpe ratio $\overline{SR}^{(K)}$ has the expression except N is replaced with K.

Result 3 (Distributions) The distribution of a randomly picked ex-post excessreturn is

$$\overline{R} \sim \mathcal{N}\left(\mu, \frac{\sigma^2}{T}\right).$$

The distribution of a randomly picked ex-post Sharpe ratio is approximately

$$\overline{SR} \stackrel{\cdot}{\sim} \frac{\mu}{\sigma} + \frac{1}{\sqrt{T}} \mathcal{T}_{T-1}$$

Derivations of the three results are presented in the appendix. The equations in results 1 and 2 hold approximately, and the error is quantified in the appendix as being less than 0.6% of the true values.

4 Distribution of Equity Premia

Results 1, 2 and 3 provide simple predictions to test the model. Results 1 and 2 predict the maximum (and minimum) ex-post equity premia and Sharpe ratio. Result 3 predicts the distribution of ex-post observations. Each prediction is tested against actual estimates of equity premia and Sharpe ratios.

4.1 US Equity Premium

The expected winner's ex-post equity premium in a world with zero ex-ante premium and $\sigma = 0.2$, N = 40 countries and T = 50 years of observation is 6.1%. The expected maximum Sharpe ratio is 32%.

Table (1) provides several estimates of the US realized equity premium and Sharpe Ratio. Mehr and Prescott (1985) report an equity premium of 6.2% and a Sharpe Ratio of 37%.

There is no significant difference between the historical US equity premium values and the expected maximum equity premium of 6.1%. Figure (1) shows the density of the expected maximum premium $p(\overline{R}^{(N)})$. Vertical lines drawn for each estimate in table(1). The density was calculated by drawing 10^5 Monte Carlo samples from $p(\overline{R}^{(N)})$ and applying kernel density estimation. Each estimate falls cleanly into the inner regions of the distributions, with *p*-values all greater than 5%. The Mehr and Prescott estimate of 6.1% has a *p*-value of 45%.

There is also no significant difference between the estimated Sharpe ratios and the model prediction of 32%. Figure (1) shows the density of maximum Sharpe ratio $p(\overline{SR}^{(N)})$. Each estimate falls within the distribution, with *p*-values all greater than 5%. The Mehr and Prescott (1985) estimate of 37% has a *p*-value of 41%.

These are striking results. The large observed equity premium of the US market can be entirely attributed to winner bias, where its ex-ante equity premium is zero. This does not necessarily imply that the US equity premium equals zero, but rather that its ex-post performance is consistent with a zero premium.

The magnitude of winner bias are not particularly sensitive to choices of number of countries and years of observation. Table 2 of the appendix gives values for the expected maximum equity premium under different choice of N and T, assuming $\mu = 0$ and $\sigma = 0.2$. Assuming N = 20 and T = 30, the expected premium is 5.3% and Sharpe ratio is 27%. Assuming N = 40 and T = 70, the results are 5.2% and 26% respectively. Assuming N = 40 and T = 30, they are 7.8% and 41% respectively. Neither a large number of countries or a short observation period is required to produce a plausible expected equity premium and Sharpe ratio.

It is unlikely that the ex-ante equity premium is actually zero. It must be positive for people to hold risky assets. Therefore, the preceding expected values are lower bounds to the actual expected maximum equity premium. Under the standard consumption asset-pricing model, the equity premium equals

$$E(R_t) = -\rho(R_t, m_t)\sigma(R_t)\frac{\sigma(m_t)}{E(m_t)},$$

where m_t is the stochastic discount factor and $\rho(R_t, m_t)$ is the correlation between R_t and m_t . Assuming log normal consumption growth and power utility, $\sigma(m_t)/E(m_t) \approx \gamma \sigma(\Delta \log c_t)$, where γ is the relative risk aversion, and $-\rho(R_t m_t) \approx \rho(R_t, \Delta \log c_t)$. The Shiller (2007) US consumption and market return data set displays a consumptionreturn correlation of 55%, an annual consumption volatility of 3.5% and annual return volatility of 18%. Assuming a relative risk-aversion of 2, the estimated equity premium is slightly under 1%. Using $\mu = 1\%$, the expected maximum equity premium now is 7.1% and the maximum Sharpe ratio is 37%, which compare even more favorably to US historical values.

4.2 Global Equity Premia

Results 1 and 2 predict any particular ordered (Kth) premium and Sharpe ratio given any set of countries, and result 3 predicts the distribution of these premia. This permits testing the model against the entire cross-section of global returns, and not only against US returns.

Table (4) provides a 38-country sample of long-term stock market performance measured and was compiled by Jorion and Goetzmann (1999). This is currently the most comprehensive data-set of global long-term market returns. The returns are cumulative (geometric), measured in local currencies, and are real (inflation adjusted). The reason for considering real returns is that not all countries in the sample have time-series for risk-free rates, nor do all countries have credible risk-free assets. To resolve this, I have assumed that the inflation rate equals the risk-free rate in each country, and therefore the equity premium equals the real return.

The model predicts the lowest expected ex-post equity premium and Sharpe ratio as -6.1% and -32% respectively. In the sample of 38 countries, Greece has the lowest observed equity premium and Sharpe ratio of -5.5% and -25%. These observations are not significantly different from the model results. The distributions of the minimum equity premium and Sharpe ratio are reflections about zero of the distributions for the maximum (drawn in figure (1)), and the respective *p*-values are 35% and 18%.

The distribution of cross-sectional observed premia in the model is normal with mean 0 and standard deviation $\sigma/\sqrt{T} = 0.2/\sqrt{50}$. The distribution is drawn in figure (2). The 38 observed premia are marked on this figure, and a kernel density estimate of the empirical distribution is drawn over the predicted distribution.

The empirical distribution is approximately normal with mean of 0.23% and standard deviation of 24%. The mean is not statistically different from zero: a *t*-test yields a *p*-value of 31%. The standard deviation is marginally different to 20%: a *t*-test yields a *p*-value of 4.5%. To formally test whether these distributions are statistically equal, a Wilcoxon rank sum test was performed. There is no significant difference between model and empirical distributions, with a *p*-value of 43%.

The distribution of observed Sharpe ratios in the model is a rescaled Student-t with 39 degrees of freedom and scaling coefficient of $\frac{1}{\sqrt{T}}$. This distribution is drawn over the kernel density estimate of the empirical distribution. The average observed Sharpe ratio is not significantly different from zero (*p*-value of 10%). A Wilcoxon rank sum test yields a *p*-value of 33% for the hypothesis of identical distributions.

In summary, the model correctly predicts both the maximum, minimum and distribution of observed global equity premia. World stock market performance is consistent with a zero-equity premium.



Figure 1: Left: Distribution of ex-post maximum equity premium in the model, with five estimates of the US equity premium. The expected ex-post maximum equity premium is 6.1%. There is no statistical difference between US estimates and what is expected from luck.

Right: Distribution of ex-post maximum Sharpe ratio in the model, with five estimates of the US Sharpe ratio. The expected ex-post maximum Sharpe ratio is 32%. Again, there is no statistical difference between US estimates and what is expected from luck.



Figure 2: Left: Distribution of realized equity premia predicted by model (solid), overlaid with the empirical distribution of 38 countries' realized premia (broken). The model distribution is Normal with zero mean and $\sigma/\sqrt{T} = 0.2/50$ standard deviation.

Right: Distribution of realized Sharpe ratios predicted by the model (solid), overlaid with the empirical distribution (broken). The model distribution is a scaled Student-*t* with zero mean, 39 degrees of freedom and $\frac{1}{\sqrt{50}}$ scale.

Individual observations are drawn as vertical bars in both plots.

5 Market Capitalization

The model predicts the distribution of countries' market capitalization. Although each country has identical return distributions, their market capitalizations differ due to random sampling of returns and the consequent differences in market value across countries.

5.1 Distribution of Capitalization

I define each country's market value as

$$P_{i,t} = P_{i,0} \exp\left(\sum_{\tau=1}^{t-1} R_{i,\tau}\right),\,$$

which is the usual definition of price when $R_{i,t}$ is a log-return. $P_{i,0}$ is assumed to equal 1 without loss of generality. The statistic of interest is countries' percentage of total world capitalization (*PC*):

$$PC_{i,t} = \frac{P_{i,t}}{\sum_{j=1}^{N} P_{j,t}}.$$

Since prices follow a geometric random-walk, values of $PC_{i,t}$ are stochastic and also display random-walk behavior. The expected market capitalization is $\frac{1}{N}$, although the expected maximum sample market capitalization is considerably larger than $\frac{1}{N}$.

The distribution of the percentage capitalizations is given in the following result:

Result 4 (Distribution of Capitalizations) The distribution of percentage capitalizations is asymptotically log-normal

$$PC_{i,T} \sim \mathcal{LN}(\mu_X, \sigma^2 T^2 + \sigma_X^2)$$

where $\mu_X = -\log(N) - \frac{T\sigma^2}{2} + \frac{T\sigma^2_X}{2}$ and $\sigma_X^2 = \log\left[\frac{(e^{\sigma^2 T^2} - 1)}{N} + 1\right].$

This is proven in section A of the appendix. The distribution is asymptotic in N. Monte Carlo simulations were run to assess the quality of the approximation with N = 40. There is negligible difference between the exact and log-normal distributions.

The US has currently has the largest market capitalization in the world, contributing approximately 30% of the total world capitalization (June 2008). Table (5) provides percentage capitalizations for the top 30 countries. The subsequent top 3 countries (Japan, UK and China) provide 20% of the total world capitalization.

Figure (3, left) displays the distribution of percentage capitalizations using $\sigma = 0.2$ and T = 50. The mean capitalization is $\frac{1}{40} = 2.5\%$, however the median capitalization is

less than half that value (1%). The histogram of empirical capitalizations is drawn over the distribution implied by the model. There is a reasonable fit between the empirical and theoretical distribution. A Wilcoxon test was performed, yielding a *p*-value of 18.4% for equal distributions.

The distribution of the maximum capitalization is compared with the US capitalization. Figure (3, right) plots the approximate distribution of this statistic. The expected maximum market capitalization is 29%, which almost exactly equals the US capitalization of 30%. There is no simple expression for the expected maximum capitalization; consequently, 10^5 Monte Carlo simulations were used to approximate the distribution.

In summary, the distribution of market capitalizations implied by the model matches the observed distribution of capitalizations. The expected maximum capitalization from the model is consistent with the US capitalization. This is further support for the simple model and implies that chance is a sufficient explanation for the distribution of market capitalizations.

5.2 Winner Bias in Market-Cap Weighting

Several studies estimate the global equity premium use market-capitalization weights. Due to extreme weightings towards the US, there is little difference between estimates of the global and US premium. In contrast, difference between market-cap weighted and equal weighed estimates of the global premium is very large. Dimson, Marsh and Staunton (2006) estimate a market-cap weighted global equity premium of 4.74% versus a US premium of 4.11%. Jorion and Goetzmann (1999) calculate a market-cap weighted global equity premium of 4.04% compared to a US premium of 4.32%. The equal weighted equity premium is -0.47%.

There may be to be good reasons to use market-cap weighting over equal-weighting. The US equity market is almost four times larger than the next largest equity market, Japan, and nearly one hundred times larger than the market in Chile. Equal weighting places equal importance to Chile's performance than to the US's. Unfortunately, market-capitalization weighting yields positively biased estimates of the equity premium due to winner bias. Under the conditions assumed in this paper, equal weighting yields unbiased estimates.

Result 5 (Market-Weighted Equity Premium) If all countries have an equal equity premia, the market-weighted estimate of the equity premium is positively biased.

Proof: At any particular time, there will be some lucky countries that have realized higher excess-returns than the average. Consequently, these countries have higher than average market value and market-capitalization weighting. Conversely, there will be

	Period	Equity Premium	Sharpe Ratio
Mehr and Prescott (1985)	1889 - 1978	6.18%	37%
Mehr and Prescott (2003)	1889-2000	6.92%	34%
Shiller (2007)	1871 - 2004	5.38%	31%
Siegel (1998)	1802 - 1998	4.10%	$25\%^*$
Jorion and Goetzmann (1999)	1921-1996	4.32%	27%

Table 1: Estimates of the US equity premium and Sharpe Ratio. Each estimate uses cumulative (geometric) returns.*Assuming 16% standard deviation in excess-returns.



Figure 3: Left: Distribution of percentage market capitalizations implied by the model (solid line), overlaid with the empirical distribution of market capitalizations as of 2008. The Wilcoxon test for equal distribution passes with a p-value of 18%.

Right: Distribution of the maximum percentage market capitalization implied by the model (solid line). The expected maximum is 29%, which compares favorably to the US capitalization of 30% (broken line).

unlucky countries that have received lower excess-returns than average, and consequently have low weightings. Therefore the market-weighted estimate of the equity premium over-weights high-realized returns and under-weights low-realized returns.

To quantify the extent of the bias, 10^5 Monte-Carlo simulations were run assuming 40 countries, 50 years of observation and $\sigma = 0.2$. Each simulation generated a 40×50 matrix returns $(\mathbf{R})_{i,t}$, 40 time-series of prices, and from these the percentage capitalization weighting matrix $(\mathbf{W})_{i,t}$ was calculated. The weighted global excess-return is $\mathbf{W}^T \times \mathbf{R}$.

Given an ex-ante equity premium of 0, the expected market-weighted estimate of this equity premium is 1.878%. The standard error from Monte Carlo simulation is 7.1×10^{-4} . The level of bias is independent of the assumed equity premium. The bias associated with using market-capitalization weights is therefore 1.878%. This is a substantial amount, almost half of the estimated global equity premium in the aforementioned studies.

The bias grows with higher standard deviation of returns, higher number of countries and longer time period since the expected difference between the "luckiest" and "unluckiest" sequence of returns becomes larger and the resulting weights become more extreme.

6 Model Extensions

The model so far considered is parsimonious and correctly predicts the distribution of equity premia, market capitalizations. While sufficient, it may be over-simplified. Two assumptions in the model are possibly contentious: the assumption identical distributions across countries, and independence across countries. Both assumptions are relaxed in this section.

6.1 Stochastic Means and Variances

Table (3) reports large global variation in the standard deviation of returns, from 13% to 60%, which is considerably larger than what is implicit in the model (15% to 25%). There is also considerable evidence that annualized standard deviations are not constant, both across countries (Bekaertc & Harvey, 1997) and over time (Andersen, Bollerslev, Diebold & Ebens, 2001). There is some evidence that means vary with time (Cochrane, 2000).

An extension that accommodates these phenomena is where each country's mean and standard deviation are stochastic, drawn each period from a common distribution. Countries still have equal unconditional means and standard deviations, however at a particular moment the means and standard deviations are different across countries. A natural choice for distributions is where country means are independently and identically drawn from a normal distribution and variances are drawn from a Chi-square distribution. That is,

$$R_{i,t} \sim \text{i.i.d } \mathcal{N}(\xi_{i,t}, \varepsilon_{i,t}^2), \text{ for all countries, where}$$

 $\xi_{i,t} \sim \text{i.i.d } \mathcal{N}(\mu, \gamma^2) \text{ and } \varepsilon_{i,t}^2 \sim \frac{\sigma^2}{k} \chi^2(k), \ E\varepsilon_{i,t}^2 = \sigma^2.$

Such models yield a larger ex-post maximum equity premium and Sharpe ratio than in the original model, regardless of the choice of distribution for the mean and standard deviation. The country with greatest realized returns may be lucky in two ways: it sampled high realized returns from $\mathcal{N}(\xi_{i,t}, \varepsilon_{i,t}^2)$, and it sampled large means from $\mathcal{N}(\mu, \gamma^2)$. This fact can be shown mathematically by conditioning $\xi_{i,t} = \mu$ for all i, t. We have

$$E[\max(\overline{R}_1, ..., \overline{R}_N)] = E_X[E[\max(\overline{R}_1, ..., \overline{R}_N | \xi_{i,t} = X \ \forall i, t)]]$$

>
$$E[\max(\overline{R}_1, ..., \overline{R}_N | \xi_{i,t} = \mu \ \forall i, t)]$$

since $E[\max(X_1, ..., X_N)] > \max(E[X_1], ..., E[X_N])$. The term $E[\max(\overline{R}_1, ..., \overline{R}_N)]$ is the winner's ex-post premium in the extended model, and the term

$$E[\max(\overline{R}_1, ..., \overline{R}_N | \xi_{i,t} = \mu \ \forall i, t)]$$

is the winner's ex-post equity premium in the original model.

The inequality also applies when means are constant and only the variance is stochastic. This is can be shown by Jensen's inequality: $E[\max(\overline{R}_1, ..., \overline{R}_N)]$ is monotonically increasing and strictly concave in σ^2 (as can be confirmed from result 1). Given some distribution for $\varepsilon_{i,t}^2$ satisfying $E\varepsilon_{i,t}^2 = \sigma^2$,

$$E[\max(\overline{R}_1, ..., \overline{R}_N)] = E_V[E[\max(\overline{R}_1, ..., \overline{R}_N | \varepsilon_{i,t}^2 = V \ \forall i, t]]$$

>
$$E[\max(\overline{R}_1, ..., \overline{R}_N | \varepsilon_{i,t}^2 = \sigma^2 \ \forall i, t)].$$

Similar inequalities can be proven for the maximum Sharpe ratio. The country with maximum Sharpe ratio may be lucky by both sampling high returns and low standard deviations; and thus has a higher expectation than when the standard deviation is constant.

The proceeding inequalities indicate that the original model specified in section 4 yields conservative estimates to the winner's ex-post equity premium and Sharpe ratio. More realistic models for means and variances imply a larger winner bias.

6.2 Correlation

The simple model assumes contemporary returns across countries are independent. However, it is well documented that returns across major stock markets are positively correlated. Ramchand and Susmel (1998) estimated an average correlation of 35% between the US and 17 other major markets using a GARCH model, with correlations ranging from 72% (United Kingdom) to 15% (Spain).

There are several avenues to introduce correlation into the model. The simplest is to assume all countries returns are uniformly correlated at some level $\rho \ge 0$. Returns are drawn from a multivariate normal distribution specified by:

$$\mathbf{R}_t \sim \mathcal{MVN}(\mathbf{0}, \Sigma), \ \Sigma_{i,i} = \sigma^2, \ \Sigma_{i,j} = \rho \sigma^2 \ i \neq j.$$

If $\rho = 1$, there is no difference between country returns, $R_{i,t} = R_{j,t}$ for all i, j, and therefore this case is equivalent to N = 1 and the expected maximum equity premium is zero. For lower positive correlation values, there are effectively fewer independent observations across countries, and this can be equivalently modeled by a lower N. As ρ increases, effective N decreases and the maximum expected equity premium and Sharpe ratio decrease.

Obtaining formulae for the expected maximum equity premium with correlation is difficult, and instead Monte Carlo simulation is used. Table (2) reports the expected maximum equity premium and Sharpe ratio for different values of ρ . The correlation of $\rho = 0.1$ reduces the expected premium from 6.1% to 5.8%. The correlation of $\rho = 0.4$ reduces the expected premium to 4.7%. Even with uniformly high correlation across all countries, the maximum expected equity premium is still high.

Assuming uniform positive correlation yields the most conservative estimates of winner bias. That is, it reduces the size of the winner bias more than any other correlation structure. It is unlikely all countries are uniformly correlated to one-another. A more plausible model is where certain groups of countries positively correlated, and between groups they are independent. Country attributes such as geographic proximity or trading volume are plausible reasons for such grouping. The model is formally specified as

$$\operatorname{Corr}(G_m, G_n) = 0$$
, for $m \neq n$ $\operatorname{Corr}(G_m(i), G_m(j)) = \rho$

where G_m is a group of countries and $G_m(i)$ is an individual country within the group. The average correlation across the world, defined as the expected correlation for any two randomly picked countries, is approximately

Ave Corr
$$\approx \frac{\rho}{M} \quad M \neq N$$
, and $0 \quad M = N$.

where M is the number of groups. If the group sizes are equal, the above grouping model gives similar expected values to assuming uniform correlation with a correlation value of $\frac{\rho}{M}$. Assuming $\rho = 0.4$ between group countries, and M = 4 groups (North America, South America, Europe, Asia), simulations yield an expected maximum premium of 5.9%, which is similar to the 5.8% value obtained by assuming $\frac{0.4}{4} = 0.1$ uniform correlation.

In summary, positive correlation reduces the size of winner bias. The effect is modest: under uniform correlation with 40%, the winner's expected equity premium reduces only by 1.4% to 4.7%.

7 The Future Equity Premium

What equity premium should US investors expect in the future? The main argument of this paper is that the historical US equity premium is a positively biased estimator of its ex-ante equity premium because of winner bias. Investors should expect the future observed equity premium to be substantially lower, equal to the ex-ante equity premium.

What then is the US ex-ante premium? It has been shown that historical returns are consistent with a (historical) ex-ante premium of 0. The actual value of the ex-ante premium is unobservable due the volatility in equity returns; it may also change over time. While consistent with observation, a value of 0 is perhaps too pessimistic: no risk-averse investor would hold equity in this case. The standard consumption asset pricing model predicts an ex-ante premium of

$$E(R_t) = -\rho(R_t, m_t)\sigma(R_t)\frac{\sigma(m_t)}{E(m_t)}.$$
(3)

Using past consumption data (Shiller, 2007), the estimated ex-ante premium is about 1%. If investors have confidence in consumption asset-pricing models, 1% is the best forecast of the future ex-ante and ex-post equity premia.

It has also shown that the distribution of world equity premia is also consistent with the zero equity premia model. This suggests that either countries have fairly common values of ex-ante equity premia; or that ex-ante equity premia are so uncertain that the assumption equality is best we can do. In either case, it does not seem possible to forecast the country with highest ex-ante premium. Given this uncertainty, the best strategy for investing in equity is to diversify across countries. It is unlikely that the US will remain the financial winner in the 21st century⁶. In 1900, the US was likely perceived by European investors as an emerging, unproven and risky market. Perhaps another emerging market will be the 21st century winner. It would also be prudent to diversity across asset classes if the equity premium is only 1%. Bonds have far lower return volatility than equity and therefore a leveraged portfolio of bonds and equity is superior to a portfolio of only equity.

8 Conclusion

Winner bias causes historical estimates of the US equity premium to overstate the actual premium. It has been shown that the size of winner bias is substantial and that winner bias alone can resolve the equity premium puzzle.

Winner bias was quantified in a simple and parsimonious model with zero ex-ante equity premium. Using globally averaged estimates for model parameters the model predicts that the winning country's ex-post equity premium is 6.1% and the Sharpe ratio is 32%. These results match the historical US premium of 6.2% and Sharpe ratio 37% reported by Mehr and Prescott (1985), and are not statistically different.

The model yields several other testable predictions. The model correctly predicts the smallest ex-post equity premia and Sharpe ratio, and correctly predicts the distribution of global equity premia and Sharpe ratios. It correctly predicts the distribution of countries percentage of total market capitalization. The winner's expected capitalization of 30%, which compares favorably to the current US capitalization of 29%.

The success of the model in these five predictions has strong implications. It implies that equity premia are equal across markets, or are indiscernible from being equal; it implies that the equity premium is fairly low (0-2%); and it implies that chance is a sufficient explanation for countries stock market successes and failures. A practical consequence is that US investors should expect a substantially lower equity premium in the future and should diversity across markets. It is unlikely that the US will remain the "winner" of the 21st century.

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 $^{^{6}\}mathrm{The}$ US has only has a 1 in 40 chance of being the 21st century financial winner according to the model.

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A Derivation of Results

Results 1 and 2 These are derived from the following approximation by Blom (1958): given a sample of N i.i.d normal random variables $\{x_1, ..., x_N\}$ with mean μ and variance σ^2 , the kth normal order statistic has an approximate expectation

$$E[x^{(K)}] \doteq \mathcal{QN}_{\mu,\frac{\sigma^2}{T}} \left(\frac{K-\alpha}{K-2\alpha+1}\right).$$
(4)

The optimum value of α for best fit depends on K and N. Blom proposed $\alpha = 0.375$ as a general approximation, and several authors have calculated tables of optimal α for different parameter values. The optimum value of α for the model in this paper was found to be 0.372.

The model specifies that annual excess-returns are i.i.d normal random variables, and the objects of study are the sample mean \overline{R}_j and sample Sharpe ratio \overline{SR}_j :

$$\overline{R}_j = \frac{1}{T} \sum_{t=1}^T R_{j,t}, \ \overline{SR}_j = \frac{\overline{R}_j}{S}, \ \text{where } S = \left(\frac{1}{T-1} \sum_{t=1}^T (R_{j,t} - \overline{R}_j)^2\right)^{1/2}$$

 \overline{R}_j has a normal distribution with mean μ and variance $\frac{\sigma^2}{T}$, hence result 1 immediately follows from (4) by replacing σ^2 with σ^2/T .

The distribution of \overline{SR}_j approximately a non-central student-*t*. By definition of the Student-*t*,

$$X_j := \frac{\overline{R}_j - \mu}{S/\sqrt{T}} \sim t(T-1).$$

Rearranging this expression yields

$$\frac{\overline{R}_j}{S} = \frac{\mu}{S} + \frac{1}{\sqrt{T}} X_j.$$
(5)

If $\mu = 0$, the Sharpe ratio has an exact Student-*t* distribution. Blom's approximation also applies for Student-*t* distributed variables: a sample of i.i.d. t(T - 1) random variables, $\{x_1, ..., x_N\}$ has a *K*th order expectation of

$$E[x_{(K)}] \doteq \mathcal{QT}_{T-1}\left(\frac{K-\alpha}{K-2\alpha+1}\right)$$

where QT_{T-1} is the quantile distribution of the Student-*t* with T-1 degrees of freedom. By applying an expectation operator to (5), the second result is obtained: the *K*th order expectation of $\{\overline{SR}_1, ..., \overline{SR}_N\}$ is

$$E\left[\overline{SR}^{(K)}\right] = E \quad \left[\frac{\mu}{S}\right] + \frac{1}{\sqrt{T}}E\left[X^{(K)}\right]$$
$$\doteq \quad \frac{\mu}{\sigma} + \frac{1}{\sqrt{T}}\mathcal{QT}_{T-1}\left(\frac{K-\alpha}{K-2\alpha+1}\right)$$

Two approximations have been made in the last line: that $E[X^{(K)}] \doteq QT_{T-1}$ and that $E\left[\frac{1}{S}\right] \doteq \frac{1}{E[S]} \doteq \frac{1}{\sigma}$. By Jensen's inequality, $E\left[\frac{1}{S}\right] > \frac{1}{E[S]}$ and $E[S] > \sigma$ ($Var[S^2] = E[S^2] - E[S]^2 > 0$, implying $E[S] > \sqrt{E[S^2]} = \sigma$). A less biased expression can be obtained by a Taylor expansion:

$$E\left[\frac{\mu}{S}\right] \stackrel{.}{=} \frac{\mu}{\sigma} - \frac{\mu}{\sigma^2} E[(S-\sigma)] + \frac{\mu}{\sigma^3} E[(S-\sigma)^2]$$
$$= \frac{\mu}{\sigma} + \frac{3\mu}{\sigma} (1-c_4)$$

where $c_4 = \sqrt{\frac{2}{n-1}} \frac{\Gamma(\frac{n}{2})}{\Gamma(\frac{n-1}{2})} = 1 - \frac{1}{4T} - \frac{7}{32T^2} - O(n^{-3})$. For $T = 50, c_4 = 0.9949$. The model considered has $\mu = 0$, hence it is unnecessary to make the above correction

for the estimated Sharpe ratios. For models with $\mu > 0$, the adjustment is minor.

Result 4 The log-percentage capitalization is

$$\log(P_{i,T}) = \log(P_{i,T}) - \log\left(\sum_{j=1}^{N} P_{j,T}\right).$$

The distribution of log-market values is normal:

$$\log(P_{i,T}) = \sum_{\tau=1}^{T} R_{i,\tau} \sim \mathcal{N}(\mu T, \sigma^2 T^2).$$

The sum of market values, $\sum_{j=1}^{N} P_{j,t}$ has no closed-form distribution, but is well approximated by the log-normal distribution; furthermore, it is asymptotically log-normal

as $N \to \infty$. The Fenton-Wilkinson (Fenton, 1960) matched moment approximation to this sum is

$$\sum_{j=1}^{N} PC_{j,T} \sim \mathcal{LN}(\mu_X, \sigma_X^2)$$

where $\mu_X = \log(N) + \mu T + \frac{\sigma^2 T^2}{2} - \frac{\sigma_X^2}{2}$ and $\sigma_X^2 = \log\left[\frac{(e^{\sigma^2 T^2} - 1)}{N} + 1\right]$. The logarithm of this sum is therefore approximately normal, with mean μ_X and variance σ_X^2 .

It follows that

$$\log(P_{i,T})\dot{\sim}\mathcal{N}(\mu T - \mu_X, \sigma^2 T^2 + \sigma_X^2 + 2\gamma)$$

where $\gamma = Cov [\log(P_{i,t}), \log(\sum P_{j,t})] = O(N^{-1})$. For sufficiently large N and/or T this correlation term is insignificant compared to $\sigma^2 T^2 + \sigma_X^2$. The result immediately follows by raising both sides of the relation to e.

B Error in Approximate Equations

1

The error between the approximate values given by result 1 and 2 and the true values was quantified using Monte Carlo simulation. The true values of $E[\overline{R}^{(N)}]$ and $E[\overline{SR}^{(N)}]$ were estimated by 10⁵ Monte Carlo draws:

$$E[\overline{R}^{(N)}] := \frac{1}{10^5} \sum_{k=1}^{10^5} \overline{R}_k^{(N)}, \ E[\overline{SR}^{(N)}] := \frac{1}{10^5} \sum_{k=1}^{10^5} \overline{SR}_k^{(N)}$$

where $\overline{R}_k^{(N)}$ equals the maximum sample average in a simulation of N countries over T periods. The optimum alpha of 0.372 was determined by minimizing the squared error across 20 pairs of N and T for $\sigma = 0.2$ The exact values and values derived from results 1 and 2 are shown in table 2. The relative error in the equation for maximum equity premium is 0.09% and for the maximum Sharpe ratio is 0.58%. The equation for maximum Sharpe ratio is downward biased: the correct value is slightly higher.

Correlation	Maximum Premium	Maximum Sharpe Ratio
$\rho = 0$	6.1%	32%
$\rho = 0.1$	5.8%	30%
$\rho = 0.2$	5.5%	28%
$\rho = 0.4$	4.7%	25%
ho = 0.6	4.0%	20%

Table 2: Effect of uniform positive correlation across countries on the expected maximum equity premium and Sharpe Ratio. Expectation values were obtained by 10^5 Monte Carlo simulations. The equivalent N value is the required number of independent countries to obtain an equal expectation value.

	True Value		Approximation	
	$E[\overline{R}^{(N)}]$	$E[\overline{SR}^{(N)}]$	$E[\overline{R}^{(N)}]$	$E[\overline{SR}^{(N)}]$
N = 20, T = 30	6.818	35.58	6.814	35.44
N = 40, T = 30	7.871	41.46	7.867	41.34
N = 60, T = 30	8.438	45.07	8.437	44.62
N = 20, T = 50	5.290	27.30	5.278	27.01
N = 40, T = 50	6.094	31.55	6.093	31.37
N = 60, T = 50	6.559	33.99	6.540	33.77
N = 20, T = 70	4.459	22.72	4.461	22.67
N = 40, T = 70	5.154	26.41	5.150	26.28
N = 60, T = 70	5.530	28.42	5.524	28.26
Relative Error (%)			0.09	0.58

Table 3: Maximum equity premium and Sharpe ratio under 9 pairs of N and T. The approximation for maximal Sharpe ratio is downward biased by 0.58%.

Country	Period	Real Return	Std. Deviation	Sharpe Ratio
United States	1/21 - 12/96	4.32	15.84	27.27
Canada	1/21 - 12/96	3.19	16.65	19.16
Austria*	1/25 - 12/96	1.62	19.49	8.31
Belgium	1/21 - 12/96	-0.26	18.97	-1.37
Denmark	1/26 - 12/96	1.87	12.69	14.74
Finland	1/31 - 12/96	2.07	17.07	12.13
France	1/21 - 12/96	0.75	21.25	3.53
Germany*	21 - 96	1.91	24.93	7.66
Germany	1/21 - 7/44	2.23	34.26	6.51
Germany	1/5/-12/96	6.00	15.6	38.46
Ireland	1/34 - 12/96	1.46	15.02	9.72
Italy	12/28 - 12/96	0.15	25.66	0.58
Netherlands	1/21 - 12/96	1.55	14.8	10.47
Norway	1/28 - 12/96	2.91	17.9	16.26
Portugal*	31 - 96	-0.58	31.2	-1.86
Portugal	12/30-4/74	1.16	14.69	7.90
Portugal	3/77 - 12/96	5.63	47.68	11.81
Spain^*	1/21 - 12/96	-1.82	16.00	-11.38
Sweden	1/21 - 12/96	4.29	16.65	25.77
Switzerland	1/26 - 12/96	3.24	14.73	22.00
United Kingdom	1/21 - 12/96	2.35	15.68	14.99
Czechoslovakia	1/21 - 4/45	3.79	12.84	29.52
Greece	7/29 - 9/40	-5.50	21.61	-25.45
Hungary	1/25-6/44	2.80	26.58	10.53
Poland	1/21 - 6/39	-3.97	65.69	-6.04
Australia	1/31 - 12/96	1.58	13.94	11.33
New Zealand	1/31 - 12/96	-0.34	12.50	-2.72
Japan [*]	21 - 96	-0.81	34.69	-2.33
Japan	1/21 - 5/44	-0.34	15.79	-2.15
Japan	4/49 - 12/96	5.52	18.90	29.21
India	12/39 - 12/96	-2.33	16.13	-14.45
Pakistan	7/60-12/96	-1.77	15.23	-11.62
Philippines	7/54-12/96	-3.65	37.21	-9.81

Table 4: Long term performance of global stock markets as reported by Jorion and Goetzmann (1999). Annual compounded real returns are reported as percentages. Real returns are measured in local currencies, and deflated by consumption price indices. The US has the highest equity premium and Sharpe ratio, and Greece has the lowest. Several countries (*) experienced gaps in return time-series due to conflict or economic crisis. Romania was omitted from the original sample since only four years of returns were observed.

Country	Period	Real Return	Std. Deviation	Sharpe Ratio
$\operatorname{Argentina}^*$	47 - 65 - 75 - 96	-4.8	60.28	-7.96
Argentina	9/47 - 7/65	-25.09	32.73	-76.66
Argentina	12/75 - 12/96	16.71	87.83	19.03
Brazil	2/61 - 12/96	-0.17	51.93	-0.33
Mexico	12/34 - 12/96	2.3	24.45	9.41
Chile*	27 - 96	2.99	29.05	10.29
Chile	1/27 - 3/71	-5.37	21.85	-24.58
Chile	1/74 - 12/96	15.52	36.25	42.81
Colombia	12/36 - 12/96	-4.29	21.78	-19.70
Peru*	41 - 96	-4.85	32.35	-14.99
Peru	3/41 - 1/53	-12.36	14.15	-87.35
Peru	1/57 - 12/77	-9.88	9.08	-108.81
Peru	12/88 - 12/96	30.45	87.98	34.61
Uruguay	3/38 - 11/44	2.42	29.66	8.16
Venezuela	12/37 - 12/96	-2.04	24.84	-8.21
Egypt	7/50 - 9/62	-2.84	12.54	-22.65
Israel	1/57 - 12/96	3.03	22.96	13.20
South Africa	1/47 - 12/96	-1.76	15.89	-11.08
Mean	52	0.23	23.6	2.97
Median	63	1.10	19.2	5.58
	00	1110	10.2	0.00

Country	% Market Cap.
US	29.9
Japan	8.2
UK	6.8
China	5.4
France	4.4
Hong Kong	4.3
Canada	3.7
Germany	3.6
Brazil	2.8
Australia	2.6
Switzerland	2.2
India	2.1
Italy	1.8
Spain	1.8
South Korea	1.8
Russia	1.8
Taiwan	1.5
Argentina	1.1
Sweden	1.0
Saudi Arabia	0.9
Netherlands	0.9
Singapore	0.9
Mexico	0.8
South Africa	0.8
UAE	0.4
Kuwait	0.4
Chile	0.4
Israel	0.4
Egypt	0.2
Qatar	0.2
Total	93.1%

Table 5: Percentage of world stock market capitalization by country in June 2008. Data compiled by Seeking Alpha (2008).