Executive Summary

• Real-world retirees exhibit several behaviors that conflict with the predictions of canonical retirement income models. Often, this is presented as evidence of irrational behavior on the part of retirees.

• This paper, the first in a two-part series, takes a different approach. A key component of retirement is uncertainty: We do not know how long assets must last or even how much we will have to spend.

• Uncertain future spending needs dramatically alter the results of typical retirement income models and generate predictions that more closely reflect real-world behaviors.

INTRODUCTION

The literature on the savings and spending behavior of retirees spans academia, financial advisors and industry professionals. Often, the real-world behavior of retirees is in conflict with what would be predicted by rational agents behaving according to economic models of retirement income.

These models typically begin with savings and investment decisions defined over the retiree’s remaining life cycle. Much like the financial industry, these models focus on how to manage an individual’s assets. At the same time, there is an equally large literature in economics describing how real-world spending, savings and portfolio allocation outcomes are heavily influenced by realized liabilities in retirement. This paper marries these two approaches in a single analytical framework. The inclusion of uncertain, unhedgeable liabilities helps illuminate several otherwise irrational retiree behaviors.

The principal contribution of this paper is to propose, parameterize and solve a life-cycle decumulation problem with uncertain liabilities. Uncertain future spending alters a household’s problem from one with even, predictable needs to one in which there is great (and likely increasing) uncertainty about both how much money will be needed later in life and exactly when it will be necessary. The results help address several empirical puzzles in retiree behavior.

In the first section, a typical asset-focused retirement income model is presented and solved. Several conclusions of this model are at odds with real-world behaviors. Although there are many such puzzles, this paper focuses on wealth drawdown rates that are too slow, consumption that is too volatile and
annuitization rates that are too low. The second section reviews the literature that shows a plausible connection between uncertain spending needs in retirement and real-world savings and investment decisions. Finally, the canonical retirement income model is augmented with a realistic parameterization of uncertain liabilities and is solved.

1. A TYPICAL MODEL

In this model, a retirement-age investor chooses how much of their initial wealth $W_0$ to consume in each period of their retirement, with preferences over consumption in period $t$ given by $U(c_t)$, a rate of preference discounting $\beta < 1$ and a survival rate given by $\pi_t < 1$. Formally, the investor solves

$$\max_{\{c_t\}_{t=0}^T} \sum_t \beta^t \pi_t U(c_t).$$

Subject to the budget constraint that their total consumption must be affordable given their initial wealth,

$$\sum_t c_t = W_0.$$ 

This leads to the well-known Euler equation relating consumption between periods:

$$U'(c_t) = \beta \pi_t U'(c_{t+1}).$$

For example, constant relative risk aversion (CRRA) preferences

$$(U(c_t) = \frac{c_t^{1-\rho}}{1-\rho})$$
yields an optimal consumption profile that declines ($\beta \pi_t < 1$) according to the following relationship:

$$\frac{c_{t+1}}{c_t} = (\beta \pi_t)^{\frac{1}{\rho}}.$$ 

When this Euler equation is combined with the budget constraint, the optimal amount of wealth allocated to consumption in each period is uniquely identified. The spending problem here is distinct from an asset allocation problem. It is possible to say a great deal without considering asset markets. While this is an obvious simplification, such an approach has the advantage that the conclusions and interpretation of the results do not depend on assumptions about the future of the capital markets.

Typical implementations of this model include uncertain rates of return, uncertain investment or inflation outcomes and choice over asset allocation. Though the details may differ, a model such as this is an appealing characterization of the problem the retiree faces. These sorts of models have formed the foundation of much retirement income research since their introduction over 50 years ago in Yaari (1965). This ubiquity is somewhat surprising. There are a number of implications of this framework that do not map to actual observed behavior.

**Puzzle 1: Low decumulation rates**

The first issue concerns the rate that assets are spent down. The model above implies that retirees should draw down their assets much faster than is seen in the data. Even if we attempt to slow down the model predictions with conservative assumptions on life expectancy and discounting, it is nearly impossible to reconcile the model with actual behavior without adding to its structure.

Initially, we consider three hypothetical cases (see Exhibit 1). Case 1 uses survival rates for a 65-year-old male, with a rate of time preference of 2.5% and a coefficient of relative risk aversion of 4. Case 2 is identical, but for a 65-year-old female (with longer life expectancy). Finally, Case 3 is an upper bound of what is possible with parameters alone: It represents an individual who will live to age 105 with 100% probability and has no rate of time preference.

**Exhibit 1: Preference parameters**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival rates</td>
<td>$\pi$</td>
<td>Male</td>
<td>Female</td>
<td>105</td>
</tr>
<tr>
<td>Discounting</td>
<td>$\beta$</td>
<td>2.5%</td>
<td>2.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\rho$</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Hypothetical example for illustrative purposes only. Source: PIMCO

Exhibit 2 depicts the model-implied behavior for the three parameterizations above, alongside actual decumulation rates as documented by the Employee Benefit Research Institute (EBRI) and Coile and Milligan (2009). All of these specifications, even the unrealistically long-lived, very patient version, would decumulate wealth throughout retirement much faster than

**Exhibit 2: Model-implied wealth decumulation rates versus actual behavior**

Hypothetical example for illustrative purposes only. Source: Author’s calculations, EBRI (2018), Coile and Milligan (2009)
actual retirees would. The model predicts that by age 75 a retiree would have spent down to 65%–75% of their assets, while real-world retirees still hold 90%-plus of their initial balance. (In fact, Coile and Milligan documents a slight increase in asset balances after age 65.)

In short, it is not possible to bridge the gap between model predictions and actual behavior with different parameters.

There are many potential behavioral explanations for this phenomenon. Some show promise, though it is generally difficult to reconcile a far-sighted reluctance to spend in retirement with the well-known myopic unwillingness to save while working. Many in the retirement industry simply force their models to have slower-than-optimal spending rates. This constrains the problem but does not explain it. Instead, with modest, realistic additions to this framework, it is possible to produce much slower decumulation rates, closer to what is seen in real-world data, without appealing to irrational behavior on the part of retirees. First, though, let us describe another puzzle.

### Puzzles 2 and 3: Volatile consumption and lack of annuity purchases

Retirees in Yaari-style models smooth out their consumption. Any unexpected shocks to wealth manifest evenly in consumption over the remaining lifetime as near-even shifts from previous levels. In the world described by the model above, spending volatility is suboptimal. Retirees should strongly favor a steady replacement rate, and their primary risk is outliving their assets (often referred to as "longevity risk"). An annuity, which provides a fixed payment for as long as the individual is alive, is a well-paired product for such a framework. In general, the actuarial rate of return on an annuity is the Social Security payment equal to the statutory maximum for the next section, we will explore one of these.

\[
\max_{\{c_t\}_{t=0}^{T}} \sum_{t} \beta^t \pi_t U(c_t + Ann + SS)
\]

s.t.

\[
\sum_{t} c_t + A_0 = W_0
\]

Ann = \frac{A_0}{P}

where \( SS \) is the Social Security payment, \( Ann \) is the amount of the annuity payment, \( A_0 \) is the amount of initial wealth invested in the annuity and \( P \) is the annuity’s price. For simplicity, we set the Social Security payment equal to the statutory maximum for an individual claiming benefits at their full retirement age (\$34,300 per year in 2019). The annuity is priced above the actuarially fair value to reflect actual market prices for immediate nominal annuities. Even when annuities are "expensive," however, an agent in this model heavily favors annuitization.

**Footnotes:**

2 Annuities are subject to the claims-paying ability of the issuing insurance company. PIMCO does not offer insurance guaranteed products or products that offer investments containing both securities and insurance features.

3 Fellowes (2017).

4 Roy, Kim-Steiner (2019)

5 They also discuss circumstances in which annuities may be less attractive. In the next section, we will explore one of these.

6 This is usually referred to by the inverse: The "money’s worth" of an annuity is the ratio of net present value of expected payouts to the price. Estimates in the literature show money’s worth values of approximately 85% (Brown, Mitchell and Poterba 2000). The baseline case here is slightly more expensive (80%), and annuities are still heavily favored.
These shocks must not be recreational; barring some requirement for the
expense, they would not be consumed. (The marginal utility of the expense in a
state where it is not required is zero.) This may not be an accurate description
for routine or minor medical expenses, but it is certainly plausible for the
large and volatile expenses that drive the bulk of the uncertainty. That is, this
framework requires that retirees do not purchase unnecessary, recreational
cancer treatments or emergency surgeries.

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10 T. Rowe Price (2017)
households in the highest percentile will see over $600,000 in medical spending. Though these shocks occur strictly outside of asset markets, they affect saving and spending behavior.

There is substantial literature detailing the relationship between healthcare expenses and savings and the portfolio-choice behavior of the elderly. De Nardi, French and Jones (2010) show that medical expenses are a key driver of low decumulation rates. They find that in the absence of medical expenses the rate of drawdown of wealth would more than double between the ages of 74 and 84, an effect that dominates the magnitudes of other common explanations, such as bequest motives. Coile and Milligan (2009) document significant wealth and asset allocation consequences of health expenses in retirement, including the sale of stocks and drawdown of IRAs, as well as a reduction in primary housing assets after health shocks. Rosen and Wu (2004) show that in addition to lower overall levels of assets, sick households hold a higher fraction of their portfolios in low-risk assets than do healthy households; particularly relevant for investment advisors, this effect appears to be twice as large as the retirees’ overall attitudes toward risk. Similarly, Poterba, Venti and Wise (2017) estimate that from 1992–2008 households with “excellent” self-reported health experience accumulated nearly 50% more assets than those with “poor” health did – equivalent to an extra 250 basis points (bps) of asset returns when annualized. In their 2011 paper, Poterba, Venti and Wise note similarly large effects and, like Coile and Milligan, show that people deploy their home equity and nonannuitized wealth as a precautionary reserve for very long-life or substantial medical outlays. The consequences of healthcare shocks on wealth and portfolio choice in retirement are large, especially when compared with the impact of typical risk and asset allocation modifications advocated in the industry.

Healthcare costs are obviously important, though they are only one example of uncertain or unanticipated future expenses. Given the array of potential risks and uncertainties, it is not economical (or even feasible) to purchase complete insurance for every eventuality. However, readily available data on the magnitude of these expenses allows us to explore this question. Unsurprisingly, both the mean and the variance of healthcare expenses increase with age, and the distribution of health expenses has a very large right tail. For simplicity, we assume annual required expenses are independently distributed, and follow distributions based on the data on out-of-pocket medical expenses by age reported in Jones et al. (2018). Exhibit 4 shows the resulting distribution of required healthcare expenses.

Exhibit 4: Parameterized out-of-pocket healthcare expenses ($000)

<table>
<thead>
<tr>
<th>Age</th>
<th>65</th>
<th>75</th>
<th>85</th>
<th>95</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>µ</td>
<td>0.41</td>
<td>0.98</td>
<td>1.37</td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>σ</td>
<td>1.34</td>
<td>1.39</td>
<td>1.46</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>3.1</td>
<td>5.9</td>
<td>9.3</td>
<td>13.2</td>
<td>126</td>
</tr>
<tr>
<td>Median</td>
<td>1.5</td>
<td>2.7</td>
<td>3.9</td>
<td>5.2</td>
<td>116</td>
</tr>
<tr>
<td>75th percentile</td>
<td>3.6</td>
<td>6.7</td>
<td>10.3</td>
<td>14.2</td>
<td>150</td>
</tr>
<tr>
<td>90th percentile</td>
<td>7.8</td>
<td>14.9</td>
<td>23.9</td>
<td>34.0</td>
<td>193</td>
</tr>
<tr>
<td>95th percentile</td>
<td>12.1</td>
<td>23.5</td>
<td>38.5</td>
<td>55.8</td>
<td>222</td>
</tr>
</tbody>
</table>

Hypothetical example for illustrative purposes only. Source: Author’s calculations

Values are in thousands. Lifetime values reflect the Social Security Administration’s published survival rates for a 65-year-old male. The simulation is drawn from a lognormal distribution parameterized by mean µ and variance σ².

Once it is weighted to reflect survival rates, this process recovers a lifetime distribution of out-of-pocket costs similar to what is observed in the data (Jones et al. 2018 and EBRI 2014), with the top percentiles exceeding $200,000 in present value. With a median net worth at retirement of approximately $250,000 in 2016, according to the Survey of Consumer Finances, it is no wonder that so many retirees fear they may not be able to afford their healthcare expenses in retirement.

3. A MODEL OF UNCERTAIN CONSUMPTION REQUIREMENTS

We now extend the model in Section 1 so that preferences are defined over expected utility, itself a function of consumption in excess of some unknown minimum level \( h_t \):

\[
\max_{\{c_{t}\}_{t=0}^{T}} \sum_{t} \beta_t \pi_t E[U(c_t - h_t)] \quad \text{subject to} \quad c_t \leq W_t + SS + Ann_t - h_t.
\]

If the required consumption exceeds available funds that period, then all assets are depleted and consumption is fixed at a guaranteed minimum level \( c_t \) for all remaining periods:

11 Jones et al. (2018)
If \( h_t > W_t + SS + \text{Ann}_t \), \( \{c_{t+s} - h_{t+s}\}_{s=0}^T\) = \( \{c_{t+s}\}_{s=0}^T \), \( \{W_{t+s}\}_{s=0}^T = 0 \).

This seems realistic. Individuals receive Medicaid coverage with very small out-of-pocket costs only after paying a deductible of essentially all their remaining assets.\(^{13}\) Of course, with any type of guarantee, it is possible for a rapid divesting of all assets to be the dominant strategy, as this maximizes the value of the guarantee for the remaining years. This is not a widely observed strategy among retirees (and does not reflect typical guidance from financial professionals), suggesting that real-world welfare guarantees represent a rather low level of consumption. Consistent with this, we select a guarantee equal to the fifth percentile of income for individuals in the U.S. aged 65 and over.\(^{14}\) Reasonable changes in the level of the guarantee will impact the magnitude of the results in this paper but will not affect their existence.\(^{15}\)

With uncertain expenses, wealth decumulation rates become state dependent. Optimal consumption in each year \( (c_t) \) is given by a function of age, current wealth levels \( (W_t) \) and current minimum spending requirements \( (h_t) \): \( c^*(t, W_t, h_t) \). Given the process for spending requirements \( (h_t) \) in Exhibit 4, it is possible to numerically solve for the optimal consumption function through recursion.

This addition to the model leads to substantively different behavioral predictions, particularly for the three puzzles discussed in the first section: wealth decumulation rates, consumption volatility and annuitization rates.

**Slower wealth decumulation**

Unsurprisingly, an uncertain future liability stream increases precautionary savings motives (Deaton 1991; Carroll 1992; Hubbard, Skinner and Zeldes 1995). This desire to self-insure against risky future spending increases the motivation to preserve assets and slows the rate of wealth decumulation.

With this new model, individual, nonmarket risks suddenly appear very relevant to retirement planning. In Exhibit 5, we depict the average wealth decumulation under the model with an uncertain liability process for a retiree with initial wealth of $1 million (“Precautionary”), a process for a retiree who was very lucky and saw no required expenses (“Healthy”), a process for a retiree who was very unlucky and in the fifth percentile of the distribution and, finally, the naive decumulation rates from the canonical Yaari-style model discussed in Section 1 (“Naive”).

\[\text{Exhibit 5: Wealth decumulation with uncertain liabilities}\]

\[\text{Healthy} \quad \text{5th percentile} \quad \text{Naive} \quad \text{Precautionary}\]

Consistent with the empirical evidence, health outcomes significantly affect retirees’ remaining wealth. A healthy 85-year-old has approximately 45% more assets than an individual in the lowest fifth percentile of the cumulative distribution, which is still slightly higher than the remaining wealth predicted by the canonical model.

**Volatile consumption: Joint targeting of income and wealth**

In this model, required spending can be funded in one of two ways: Either current spending can fall, or wealth can fall to meet the required healthcare shocks. The results suggest that retirees will raise and lower current discretionary spending to partially offset required outflows. Discretionary spending in retirement will be volatile, as this volatility helps preserve wealth for future needs. Early in retirement, uncertain required expenses are funded through larger reductions in discretionary spending than they are later in retirement. Only very late in retirement does the opposite relationship hold as retirees finally spend down their excess wealth. Exhibit 6 shows the fraction of uncertain expenses that are funded by changes in current discretionary consumption (the remainder is funded from wealth), by age. Early in retirement, as much as 15% of required expenses are paid for by immediate decreases in discretionary consumption. This share declines rapidly with age until age 70, when 4% of shocks are funded by changes in consumption and 96% from asset balances.

\[\text{Exhibit 6: Fraction of uncertain expenses funded by changes in current discretionary consumption}\]

\[\text{Healthy} \quad \text{5th percentile}\]

\[\text{Hypothetical example for illustrative purposes only. Source: Author’s calculations}\]
Exhibit 6: Funding uncertainty: Wealth versus discretionary consumption

As a percentage, discretionary consumption is five times as responsive as wealth to required expenses at the beginning of retirement, when a 1% decline in wealth corresponds to a 5% decline in consumption. This falls over time until the elasticity of consumption and wealth converge after 10 to 15 years. A declining profile is the reverse of the effect of wealth shocks in a Yaari-style model, in which the retiree would more significantly draw down their wealth early in retirement to stabilize lifelong income. Between the ages 70 and 85, the funding pattern nearly matches the canonical model, and late in retirement we see accumulated precautionary wealth increasingly used to help dampen the volatility in late-retirement discretionary consumption.

The patterns in discretionary consumption volatility suggest different roles for assets in early, middle and late retirement. Initially, preserving assets is paramount and spending is relatively responsive to ensure wealth can be maintained to fund a full retirement. As time passes, the assets are increasingly relied upon to finance late-retirement needs. Exhibit 6 suggests that assets are spent down differently depending on whether the retiree is in early, middle or late retirement.

Lower annuity purchases

Uncertain future expenses lead the retiree to tolerate more income volatility early in retirement in exchange for the preservation of future wealth. It is no surprise, then, that retirees in this model would place a lower value on a stable income stream. Higher, fixed payments are not useful if they deplete assets enough at the outset so that the retiree is unable to absorb potentially large future expense shocks. The behavioral literature explicitly supports this precautionary aversion to annuities: Beshears et al. (2014) document the top self-reported reasons for not purchasing an annuity as “[I] want to ensure I have enough income later in life,” “[I] want flexibility in the timing of my spending,” and “[I] may have a big (unanticipated) spending need.” They also report that presenting annuities and highlighting the loss of “flexibility and control” of assets is associated with the greatest reduction in annuity purchases.

As shown in Exhibit 7, optimal annuity purchases are cut by 50%–100% relative to a Yaari-style model. Based on these results, precautionary saving appears to play a part in the limited real-world appeal of annuities. Annuity purchases fall more with lower levels of initial wealth, as relatively larger unknown expenses provide a stronger desire to preserve assets when they are low.

16 The effect under the naive model can be analytically determined in closed form as the derivative of the optimal consumption rule with respect to wealth in each period.

17 Here the focus is on purchases at retirement. An increasing survivorship premium would increase the appeal of late-retirement, deferred and actuarially fair rolling one-year annuities as an investment rather than as insurance, as described in Pang and Warshawsky (2010) and Brown, Davidoff and Diamond (2005).
Exhibit 7: Optimal annuity purchase with uncertain liabilities

<table>
<thead>
<tr>
<th>Life expectancy</th>
<th>Risk aversion</th>
<th>Discounting</th>
<th>Wealth ($000)</th>
<th>Optimal annuity share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Male</td>
<td>4</td>
<td>2.50%</td>
<td>$1,000</td>
<td>Yaari model 100%</td>
</tr>
<tr>
<td>2 Female</td>
<td>4</td>
<td>2.50%</td>
<td>$1,000</td>
<td>Uncertain liabilities 44%</td>
</tr>
<tr>
<td>3 105</td>
<td>4</td>
<td>0.00%</td>
<td>$1,000</td>
<td>Yaari model 100%</td>
</tr>
<tr>
<td>4 Male</td>
<td>2</td>
<td>2.50%</td>
<td>$1,000</td>
<td>Uncertain liabilities 61%</td>
</tr>
<tr>
<td>5 Male</td>
<td>8</td>
<td>2.50%</td>
<td>$1,000</td>
<td>Yaari model 100%</td>
</tr>
<tr>
<td>6 Male</td>
<td>4</td>
<td>2.50%</td>
<td>$210</td>
<td>Uncertain liabilities 16%</td>
</tr>
<tr>
<td>7 Female</td>
<td>4</td>
<td>2.50%</td>
<td>$210</td>
<td>Yaari model 0%</td>
</tr>
</tbody>
</table>

Hypothetical example for illustrative purposes only. The model outputs included here are not based on any particularized financial situation, or need, and nothing contained herein should be considered investment or retirement advice. PIMCO does not offer insurance guaranteed products or products that offer investments containing both securities and insurance features. The model is limited to analyzing the optimal annuitization rates. Investors should speak to their financial professional regarding the investment mix that may be right for them based on their financial situation and investment objectives. Source: Author's calculations.

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Life expectancy data is from the Social Security Administration. Annuities are priced at a money’s worth of 80%. Life expectancy of 105 represents a retiree who lives to age 105 with 100% probability. Annuity shares are in addition to a guaranteed Social Security payment equal to the statutory maximum for a full retirement age claimant.

Of particular note is the effect of life expectancy and risk tolerance. Absent spending requirements, a longer life expectancy for an individual should increase the appeal of a lifetime annuity. Here we see the opposite: The long-lived 105-year-old – who would normally be an ideal annuity customer – actually has a stronger desire to avoid annuities in a world with uncertain required spending. Although annuities provide an exceptionally high rate of return in this case, the retiree also runs a higher risk of larger expenses later in retirement that exceed the obtainable income stream from annuitization.\(^1\) Using the healthcare expense distribution in Exhibit 4, a 105-year life expectancy suggests an average lifetime out-of-pocket expense of nearly half a million dollars and a 95th percentile cost of over $750,000! The increased appeal of longevity protection is weighed against the increased desire to accumulate precautionary wealth. These results suggest that the second effect appears to dominate the first. Risk tolerance has a similar counterintuitive effect: Increases in risk aversion decrease the appeal of annuities, reversing the conclusion of typical retirement income models. With uncertain liabilities, longevity risk is no longer the retiree’s primary concern.

CONCLUSION
Real-world retirees exhibit several behaviors that conflict with the predictions of canonical retirement income models. They appear overly averse to spending their accumulated wealth, their consumption is far too volatile, and they buy far too few annuities. With few exceptions, the response of the retirement industry to this behavior has been to try and persuade retirees to behave more like the model prescribes. This included designing drawdown strategies, facilitating annuity purchases and designing products to help mitigate volatile spending.

The focus on the retiree’s assets ignores large risks that real-world retirees must manage. They face expenses that are not easy to forecast or anticipate. Even when these risks cannot be hedged by financial instruments, they have significant impacts on behavior. This is not theoretical: There is a large literature that shows health status and health expenses dramatically impact asset balances, portfolio allocations and total spending. Indeed, the desire to save for future healthcare expenses is a well-documented self-reported concern, particularly among the elderly.

This paper explicitly incorporates unknown required future expenses into the retirement planning problem by parameterizing a healthcare expense process based on real-world out-of-pocket expenses. Incorporating this feature appears to help close the gap between model-predicted and real-world behavior. This view can partially rationalize a series of otherwise puzzling behaviors, including slow drawdown of retirement wealth, excess consumption volatility and a lack of annuitization.

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\(^1\) We do not consider state-contingent annuities – contracts that pay more in certain states potentially unrelated to financial markets. These products are essentially nonexistent. Brown, Davidoff and Diamond (2005) explicitly mention incomplete markets (those without state-contingent annuities) combined with precautionary savings motives – exactly as we have in this model – as one in which annuitization may not be optimal.
REFERENCES


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