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No Portfolio Is an Island

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The authors incorporated nonfinancial assets—industry-specific human capital, region-specific housing wealth, and pensions—into a traditional portfolio optimization and found that the optimal portfolio varies materially for different compositions of total wealth. In particular, they found that the optimal equity allocation decreases with age, riskier employment, and riskier homeownership, whereas it increases with guaranteed pension income. These results suggest that every portfolio needs to be considered in the context of an investor's total wealth.

The famous poem "For Whom the Bell Tolls," based on a prose piece by English poet John Donne (1572–1631), warns readers against thinking that the funeral bells we hear are not for us, the living: because of the interconnectedness of humankind, each of us is diminished by the loss of another. The poem begins, "No man is an island, / Entire of itself." This poem has a lesson for investors, because no portfolio is an island either.

When building portfolios, most investors tend to focus entirely on the risk and return characteristics of investments, such as cash, bonds, and stocks, ignoring the interconnectedness of their portfolios with other assets that they effectively own, such as human capital, real estate, and pensions. In many instances, these overlooked assets' value exceeds the value of the financial (i.e., liquid) wealth. For example, Becker (1993) estimated that the value of human capital is at least four times larger than the value of stocks, bonds, housing, and all other assets combined. Heaton and Lucas (2000) estimated that human capital is 48% of household wealth whereas financial assets represent only 6.8%.

A growing body of research incorporates the unique risks associated with human capital into the asset allocation decision, but a relatively limited body of research accounts for multiple dimensions of wealth and explores how the characteristics of outside wealth affect optimal portfolio choice. Although the majority of research on the subject has relied on complex utility-based consumption models, we used a familiar single-period portfolio optimization routine in our study.

Editor's note: The authors may have a commercial interest in the topics discussed in this article.

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■ *Discussion of findings.* In our study, we explored the impact of incorporating human capital, housing wealth, and pensions into the optimal portfolio choice. We found significant evidence that the optimal allocation for an investor's financial assets varies materially for different compositions of total wealth. In particular, we found that the optimal equity allocation decreases from 61% at age 25 to 26% at age 65 as an individual's human capital erodes and housing wealth and financial wealth rise. We also found that the optimal portfolio varies significantly for different types of industry-specific human capital. For instance, the optimal equity allocation is higher (lower) for a worker in an industry with a lower (higher) equity market beta. Similarly, we found that human capital is correlated with the value factor and that region-specific housing wealth also affects the optimal equity weight. Overall, we found that across 1,000 total wealth compositions considered, incorporating outside wealth results in an average increase in risk-adjusted return of 30 bps.

The total wealth approach introduced in this article can help (1) private wealth managers build more-efficient portfolios for their clients and (2) defined contribution plan sponsors implement a more customized target-date solution for their participants.

Dimensions of Wealth

Financial assets and nonfinancial assets (e.g., human capital) share common systematic risks, which may vary significantly for different people. In our study, we developed a straightforward total wealth framework to help investors build portfolios in the context of the risks associated with different dimensions of wealth. The notion of a total wealth portfolio discussed in this article is related to the idea of the extended portfolio introduced by Jennings and Reichenstein (2008). Expanding the total wealth concept beyond assets, Black, Ciccotello, and Skipper (2002) included such liabilities as consumer credit in their definition of an investor's total economic portfolio. In our study, we focused on the asset side.

The body of research on intertemporal portfolio theory has expanded considerably since Merton's (1969, 1971, 1973) seminal studies (see Viceira 2001; Wallmeier and Zainhofer 2006; Ibbotson, Milevsky, Chen, and Zhu 2007). These studies provide insight for investors in terms of how they should allocate assets over their lifetimes, with a focus on such nontradable assets as human capital. The models used in the studies are generally complex and have been relatively ignored in practice (see Cochrane 2014). In our study, we used a more straightforward framework to incorporate the varying risky assets held by an investor, making it easier for investment professionals to implement.

Cochrane (2007) argued that the optimal portfolio for an investor with nontradable income should deviate from the market portfolio to the extent that the investor is different from the average person. In particular, Cochrane emphasized two potential sources of deviation from the market portfolio for a given level of risk aversion: (1) the *relative weight* of human capital and other outside wealth as a percentage of total wealth and (2) the difference in the *riskiness* of the investor's human capital and other outside wealth compared with that of the average investor. This insight is central to the objective of this article, which is to describe the characteristics of the outside wealth empirically and to make inferences about the optimal portfolio choice given the unique characteristics of an investor's nontradable income, such as industry-specific human capital.

Although we focused on the individual or household in our study, the concept of total wealth optimization can be extended to other entities—for example, a charitable endowment, given the unique risks faced by charities that finance their operations through a combination of donations and endowment earnings (see Merton 1993; Blanchett 2014). Taking a holistic perspective of risk and adjusting the financial assets accordingly should lead to a more efficient total wealth allocation for each investor, regardless of investor type.

We considered systematic risks, not idiosyncratic risks, in our study. Idiosyncratic risks vary by investor and by asset and are far more difficult to quantify and incorporate into a portfolio optimization routine than are systematic risks. Unlike idiosyncratic risk at the security level, which can be diversified away by holding a diversified mix of securities in a portfolio, few options are available to mitigate the idiosyncratic risks associated with different types of nonfinancial assets, such as human capital. Although some forms of insurance can be used as a quasi hedge for human capital (e.g., unemployment insurance, disability insurance, and life insurance), these risks are highly personalized and beyond the scope of the general model introduced in this article.

Another caveat is that the data we considered in our empirical analysis are specific to the United States and may not apply directly in a non-US context. Data limitations and differences in statistical reporting standards across countries make it difficult to assemble a single global dataset. We believe the implications of our study are relevant to investors with human capital and other forms of nonfinancial wealth generally; however, we leave to future research an empirical analysis focused on other countries.

Financial Assets

As the most easily observable and usually most liquid portion of household wealth, financial assets tend to receive most of the attention when building a portfolio—at the expense of nonfinancial assets, which are also important. In our study, we treated financial assets as a "completion portfolio" in the context of an investor's total wealth, where the optimal portfolio minimizes the variance of total wealth for a given return and the opportunity set of financial assets is represented by commonly used and easily accessible asset classes.

The relative weight of financial assets as part of an investor's total wealth varies by investor type and age. Although younger people tend to have little financial wealth, they tend to accumulate financial wealth over their working careers through savings, which are then spent down during retirement. Financial assets are usually largest when retirement commences.

The opportunity set of investable financial assets is included in **Table 1**, along with respective index proxies, returns, and standard deviations over the test period—from the second quarter of 1993 to the first quarter of 2013, for a total of 80 quarters. Our study period begins in the second quarter of 1993 because that is the first quarter for which the change in the value of human capital can be estimated given the required industry-specific bond yield data (discussed in the next section).

We included 13 asset classes in our analysis: one cash asset class (cash); five bond asset classes (US intermediate-term bonds; US long-term bonds; US Treasury Inflation-Protected Securities, or TIPS; US high-yield bonds; and non-US bonds); five equity asset classes (US large growth, US large value, US small growth, US small value, and non-US equity); and two alternative asset classes (REITs and commodities). We intentionally selected the opportunity set to reflect asset classes that investment professionals commonly use when building portfolios for clients.

The nominal returns for the asset classes were relatively high over the study period, especially for cash and fixed income, compared with the yields

Table 1. Asset Classes, Proxies, Historical Returns, and Standard Deviations, Q2 1993–Q1 2013

			Quarterly		Annualized	
Asset Class	Index/Proxy	Name	Return	Std. Dev.	Return	Std. Dev.
Cash	Barclays US Treasury Bills	Cash	0.76%	0.53%	3.07%	1.06%
US intermediate-term bond	Barclays US Government/ Credit Intermediate	IntBd	1.40	1.68	5.71	3.37
US long-term bond	Barclays US Government/ Credit Long	LgBd	2.05	4.37	8.46	8.75
US TIPS	Barclays US Treasury: US TIPS	TIPS	1.75	2.28	7.20	4.55
US high-yield bond	Barclays US HY Corporate Bonds	HiYld	2.07	4.91	8.55	9.81
Non-US bond	Barclays Global Aggregate Excluding USD	nUSBd	1.54	4.39	6.31	8.79
US large growth	Russell 1000 Growth	LarGro	2.35	9.77	9.72	19.53
US large value	Russell 1000 Value	LarVal	2.58	8.33	10.73	16.66
US small growth	Russell 2000 Growth	SmGro	2.46	12.33	10.19	24.67
US small value	Russell 2000 Value	SmVal	2.95	9.64	12.34	19.28
Non-US equity	MSCI EAFE	nUSEq	2.15	9.43	8.87	18.86
Commodities	Dow Jones UBS Commodity	Comm	1.63	8.27	6.68	16.54
Real estate (REITs)	FTSE NAREIT All REITs	REITs	2.96	9.88	12.36	19.76
Inflation	Ibbotson SBBI US Inflation	na	0.61	0.87	2.46	1.73

na = not applicable.

available today. For example, the average annual return on cash was approximately 3.07% over the study period, which is considerably higher than the yield available on one-month Treasury bills, which was close to zero in January 2015.

We determined the weights to the 13 asset classes by using a nonlinear optimization routine in which the goal is to minimize the variance in the inflation-adjusted change for the investor's total wealth. For the optimization, only the weights to the financial assets are adjusted—all other types of wealth are considered nontradable. It is also assumed that perfectly hedging both the risk of the other asset classes (e.g., by using some form of insurance) and the covariance of the other assets with each other is impossible. Thus, this optimization routine seeks to determine the additional potential diversification benefits of incorporating the unique risks associated with different assets (and their weights) from a total wealth perspective. In this article, we refer to portfolios that are optimized entirely on the risks associated with the financial assets as *island portfolios*.

We placed three constraints on the optimization to reflect common investor considerations and to more easily isolate the differences that result from holding different amounts and types of wealth. First, there is no shorting. Second, the maximum allocation to a single asset class is 20%; this constraint ensures that the portfolio will have nonzero weights to at least five classes. Third, the return on the financial assets must equal the average quarterly return on all available asset classes over the study period (2.05%). The third constraint ensures that the resulting allocations are at least somewhat balanced across the asset classes.

Human Capital

We developed a novel approach to determining the value of human capital by incorporating growth and discount rates specific to 10 different labor industries; we found that human capital is generally positively correlated with financial assets—with an average correlation of 0.27—and that correlations vary materially across industries.

Human capital has a variety of definitions but can generally be thought of as the total economic value of a person's set of skills and talents. Human capital is a unique asset because it varies by age, health, education, occupation, industry, and experience, among other variables, and is nontradable. These traits create endowed exposures to certain risk factors that can be difficult to hedge effectively.

In the late 1960s, models developed by such economists as Samuelson (1969) and Merton (1969) suggested that investors should maintain constant portfolio weights throughout their lives. An important assumption of these models was that investors had no labor income (or human capital). Subsequent research by Wallmeier and Zainhofer (2006) and Ibbotson et al. (2007), among others, has attempted to incorporate the bond-like nature of human capital into the equity allocation decision framework. This research suggests that equity allocations should change over time as human capital is consumed (or depleted), taking the shape of a "glide path" that is common in target-date investments today.

Models used to estimate the value of human capital generally view earnings as a type of dividend from the worker's total human capital; therefore, dividend growth models are used to value human capital. Under this approach, the total value of human capital (HC) at a given point in time (t) is estimated on the basis of the worker's wage (w), an appropriate discount rate (r), and an expected wage growth rate (g)—using Equation 1. One obvious shortcoming of using Equation 1 to estimate the value of human capital is that it implicitly assumes an infinite horizon. In our study, we developed a model that addresses this shortcoming (discussed in the next section).

$$HC_t = \frac{w_t}{r_t - g_t}. \tag{1}$$

The return on human capital (r_{HC}) is estimated by observing the change in the total value of human capital over two points in time:

$$r_{HC} = \frac{HC_t - HC_{t-1}}{HC_{t-1}}. \tag{2}$$

The riskiness of human capital can then be determined on the basis of the variability of the return on human capital or some other measure. The simplest approach to estimating the return on human capital is to assume that it is equal to the changes in wages over time. This approach requires the assumption that the discount rate and the wage growth rate are constant, both across industries and over time—which does not hold in reality, a shortcoming addressed by the approach we developed in our study.

Estimating Industry-Specific Human Capital. Our approach to estimating the total value of human capital and its riskiness is motivated by the work of Ibbotson et al. (2007) and is notated as follows:

$$HC_t = \sum_n^R \frac{q_{R-n} w_t \left(1 + g_t + i_t\right)^{R-n}}{\left(1 + r_t\right)^{R-n}}, \tag{3}$$

where

HC_t = the total human capital at time t

n = the individual's current age

R = the expected retirement age (assumed to be 65)

q_{R-n} = the probability of surviving to a given age (based on the Society of Actuaries 2000 annuity mortality table for a unisex individual)

w_t = the earnings at time t

g_t = the expected earnings growth rate at time t (based on historical employment growth rates from the US Bureau of Labor Statistics)

i_t = the expected inflation rate at time t (based on historical inflation expectations from the Federal Reserve Bank of Cleveland)

r_t = the nominal discount rate at time t (based on the historical yields for various Barclays investment-grade industry bond indexes plus a term premium)

In Equation 3—an extension of Equation 1—the value of human capital is the mortality-weighted net present value of a person's future expected labor income. Pension benefits are intentionally disentangled from human capital (the rationale for which is discussed later, in the section on pension wealth).

Eiling (2013) showed that industry-specific human capital can be used to explain differences in expected returns on individual stocks, suggesting that industry affiliation has important implications for how people allocate their assets. Motivated by this finding, we believe that a key contribution of our study is using Equation 3 to estimate the value of human capital for various industries. Specifically, analyzing the changes in industry-specific human capital over time allows us to draw conclusions about the optimal portfolio choice for investors with different industry affiliations.

For our analysis, we obtained historical quarterly wage data for various industries from the US Bureau of Economic Analysis (BEA). Although available wage data go back as far as 1941 for some industries, we used only more recent values in order to match the available data for both the various asset classes in our analysis and the discount rates. An additional benefit of using more recent data is that such data are likely to be more reflective of industry risks today. We selected 10 industries for our analysis: construction, finance, government, health care, lodging, manufacturing, mining, real estate, transportation, and utilities. To provide some perspective on the relative sizes of the industries that we selected for our analysis, note that together they account for 53.70% of total full-time and part-time employment in the United States, with government being the largest industry (at 17.20%) and utilities being the smallest (at 0.39%)—all based on data from the BEA.

The discount rate (r) used to estimate the value of human capital (in Equation 3) is assumed to be the yield on the Barclays corporate bond indexes for the relevant industry. Thus, we can assume that the certainty with which the average worker in an industry is paid a salary is the same as the certainty, priced into the bond market, with which the average company in the corporate bond index can meet its coupon and/or principal payments. Furthermore, this method implicitly assumes that the debt and remuneration claims have the same seniority in the company's capital structure. Calcagno and Renneboog (2004) pointed out that the seniority of the debt claim versus the remuneration claim is a complex issue and that the relative seniority of either claim cannot be generalized.

There may be idiosyncratic reasons for a company to cease paying someone's salary, such as the person's being fired. However, these idiosyncratic shocks are irrelevant to the purpose of our study: to characterize the co-movements of financial assets and human capital that are, by definition, systematic. Note that there are systematic shocks that affect the value of human capital in a given industry but that may not affect the bond yields. For instance, an employment wave (supply of labor) in a given industry may affect the value of human capital but cannot directly affect the ability of companies to pay their debts. Despite the potential weaknesses of this approach, the theoretical justification for using the corporate bond yields to discount human capital is that the creditor and the employee in a given industry are affected by the same systematic shocks because they are paid from the same cash flow. Changes in corporate bond yields are observable in real time. Incorporating industry-specific and time-varying shocks to the discount rates is important because doing so better reflects how the expected value of human capital changes over time.

We based the discount rates for industry-specific human capital on the yields of the Barclays investment-grade bond indexes for each industry plus a term premium. We focused on the investment-grade universe and avoided high yield because the investment-grade industry indexes are better diversified in terms of number of issues, which reduces the potential impact of any one issue on the results. Also, the investment-grade industry indexes exhibit smaller differences in average level yields than their high-yield counterparts, making the investment-grade industries a more consistent and homogeneous sample. We included the term premium in an attempt to equalize the maturities among the various Barclays indexes over time and to better match the expected maturity of human capital (at retirement) to the maturity of the index. Actual maturities for the 10 indexes varied between approximately 4 and 18 years over the sample period; therefore, including a term premium helps normalize the differences that can be attributed to different industry exposures versus different durations.

We calculated the term premium by using the historical term premium for Treasury bonds for the particular month. The term premium is added to (or subtracted from) the yield of the particular industry-specific Barclays investment-grade bond index so that the maturities are the same across indexes (based on the number of years until retirement). For example, if the duration of the utilities index is 10 years but the time until retirement is 20 years, the difference in the yield between the 20-year Treasury and the 10-year Treasury is added to that month's yield for the utilities index. The maximum maturity is assumed to be 30 years, even if the time to retirement exceeds 30 years. Historical yields during various periods, along with the respective proxies for select industries, are reported in **Table 2**.

Table 2 shows that discount rates are constant across neither industries nor time. Thus, an approach that assumes a constant discount rate (a common assumption in prior research) does not accurately capture industry-specific volatility evident in the historical time series of corporate bond yields.

We used two components to estimate the expected historical nominal wage growth rates: the expected wage growth rate and the expected level of headline inflation. Both metrics are forward-looking estimates at varying historical points in time (so there is implied estimation error). We based the expected wage growth rate on the projected annual growth rate in employment for various industries, with data obtained from the Bureau of Labor Statistics (BLS). The BLS has produced projections of the labor force, industry output and employment, occupational employment, and job openings since 1966. Although forecast changes in real wages are not the same as estimated changes in employment, they are assumed to be reasonable proxies for each other—which is based on the assumption that as an industry grows (or shrinks), wages are likely to follow suit. The BLS publishes its projections

Table 2. Industry-Specific Human Capital Discount Rates for Select Months

Industry	Bond Proxy	Mar/93	Mar/97	Mar/01	Mar/05	Mar/09	Mar/13
Construction	Barclays IG Building Materials	7.77%	7.70%	7.43%	5.57%	13.23%	4.18%
Finance	Barclays IG Banking	7.96	7.62	6.72	5.30	9.96	3.50
Government	Barclays Investment Grade	7.21	7.63	7.07	5.58	8.53	3.49
Health care	Barclays IG Health Care	7.15	7.59	7.19	5.46	7.12	3.26
Lodging	Barclays IG Lodging	8.07	8.00	7.93	5.55	13.63	3.86
Manufacturing	Barclays IG Divers. Manufacturing	7.81	7.72	6.74	5.36	7.16	3.15
Mining	Barclays IG Metals & Mining	8.21	7.90	7.29	5.41	9.81	4.08
Real estate	Barclays IG REITs	7.77	7.75	7.64	5.81	14.46	3.81
Transportation	Barclays IG Transport	8.18	7.78	7.21	5.85	7.75	3.51
Utilities	Barclays IG Utility	7.64	7.70	7.28	5.50	7.45	3.56

Table 3. Growth Rates for Industry-Specific Human Capital Real Wages

	Projection Period											
Industry	1992–2005	1994–2005	1996–2006	1998–2008	2000–2010	2002–2012	2004–2014	2006–2016	2008–2018	2010–2020	2012–2022	Average
Construction	1.8%	0.9%	0.9%	0.9%	1.2%	1.4%	1.1%	1.0%	1.7%	2.9%	2.6%	1.5%
Finance	1.5	0.6	1.0	1.2	1.2	1.2	1.0	1.4	0.7	1.0	0.8	1.1
Government	–0.4	–0.8	–0.3	–0.5	–0.6	0.0	0.2	–0.4	0.3	–1.3	–1.6	–0.5
Health care	3.0	2.7	2.9	2.6	2.5	2.8	2.7	2.4	2.3	3.0	2.6	2.7
Lodging	2.6	1.5	2.9	2.9	1.3	1.7	1.6	1.3	0.8	1.0	0.9	1.7
Manufacturing	–0.2	–0.7	–0.2	0.0	0.3	–0.1	–0.6	–1.1	–0.9	–0.1	–0.5	–0.4
Mining	–0.9	–2.8	–2.5	0.1	–1.1	–1.3	–0.9	–0.2	–1.6	0.4	1.4	–0.9
Real estate	1.8	0.7	1.2	1.2	1.4	1.2	1.7	1.8	1.3	2.8	1.1	1.5
Transportation	1.6	0.6	–0.3	1.5	1.7	2.0	1.1	1.1	0.9	1.9	0.7	1.2
Utilities	1.0	0.2	1.0	–0.4	0.5	–0.6	–0.1	–0.6	–1.1	–0.7	–1.1	–0.2
Average	1.2%	0.3%	0.7%	1.0%	0.8%	0.8%	0.8%	0.7%	0.4%	1.1%	0.7%	0.8%

biannually; the projected growth rates that we used in our analysis are reported in **Table 3**.

Similar to the discount rates, which vary by industry and over time, the expected wage growth rates also vary by industry and over time. Again, this finding implies that an approach to estimating human capital that assumes a constant wage growth rate cannot capture the actual historical differences in industry expectations.

The average projected real wage growth rate for the 10 industries over the sample period is 0.8%. This value is relatively consistent with the historical difference in growth of the National Average Wage Index (as calculated by the US Social Security Administration) and inflation (Consumer Price Index for All Urban Consumers) from 1952 to 2012, which has been approximately 1.0%. For our analysis, we averaged the real growth rates on a weighted basis between the two particular periods to smooth out the changes over time.

We proxied expected general inflation (i_t in Equation 3) with the historical 20-year inflation forecast for each quarter, with data obtained from the Federal Reserve Bank of Cleveland. Similar to historical bond yields, employment growth rates, and wages, expected inflation varied over the study period. Expected 20-year inflation was approximately 3.0% at the beginning of the period and had declined to approximately 1.8% by the end of the period.

We assumed the person's age to be constant when modeling the value of human capital over time. Assuming a constant age versus assuming that a person "ages" over time allowed us to separate the effects of the natural decline in the value of human capital due to aging from changes in the value of human capital due to changes in risk. The impact of aging on the optimal portfolio choice is discussed later, in the section on total wealth analysis.

To provide readers with some perspective on the extent and statistical significance of the correlations, **Table 4** reports the correlations between the changes in value of the 10 industry-specific forms of human capital and the returns on the 13 asset classes. The assumed age for the human capital estimates in Table 4 is 45.

The correlations are statistically significant for many asset classes, generally more so for the fixed-income assets than for cash, equities, or the alternative asset classes. The average absolute correlation across all asset classes is 0.266, with a median of 0.253. These values (a correlation of ≈0.25) correspond to a p-value of approximately 0.02. The four asset classes with the highest absolute correlations, along with the highest degree of statistical significance, are intermediate-term bonds (0.45 average), long-term bonds (0.48 average), high-yield bonds (0.39 average), and REITs (0.41 average). The high correlation with fixed-income asset classes is not surprising given that we used corporate bond yields as the discount rate for human capital.

There are some notably high correlations. For example, the correlation between the human capital of the real estate industry and the return on REITs is 0.602. This relationship is intuitive, suggesting that changes in the value of REITs have a significant and positive relationship with wages in the real estate industry. The implication is that workers in the real estate industry are likely to have a lower (or no) allocation to REITs in their financial assets than workers in other industries, such as manufacturing (based on the correlations in Table 4).

Human Capital Optimizations with Primary Asset Classes

Incorporating industry-specific human capital into a portfolio optimization of 13 asset classes leads to significant differences in optimal portfolio weights with respect to both a financial assets–only optimization and the various industry-specific forms of human capital.

Table 4. Correlations between Industry-Specific Human Capital and Asset Classes, Q2 1993–Q1 2013

	Industry-Specific Human Capital									
Asset Class	Construction	Finance	Government	Health Care	Lodging	Manufacturing	Mining	Real Estate	Transportation	Utilities
Cash	–0.019	–0.012	–0.069	–0.087	–0.156	–0.013	–0.111	–0.094	–0.033	–0.095
IntBd	0.337***	0.534***	0.691***	0.502***	0.142	0.645***	0.288***	0.200*	0.517***	0.610***
LgBd	0.315***	0.570***	0.696***	0.522***	0.168	0.742***	0.331***	0.209*	0.549***	0.650***
TIPS	0.324***	0.136	0.348***	0.327***	0.241**	0.354***	0.352***	0.282**	0.282**	0.369***
HiYld	0.559***	0.346***	0.359***	0.260**	0.666***	0.079	0.369***	0.648***	0.316***	0.298***
nUSBd	0.218*	0.354***	0.447***	0.232**	0.123	0.419***	0.250**	0.161	0.331***	0.267**
LarGro	0.222**	0.107	–0.048	0.084	0.362***	–0.137	0.066	0.251**	0.099	–0.101
LarVal	0.355***	0.270**	0.078	0.155	0.388***	0.008	0.255**	0.373***	0.228**	0.067
SmGro	0.203*	0.111	–0.083	0.099	0.397***	–0.139	0.066	0.263**	0.099	–0.091
SmVal	0.324***	0.228**	0.034	0.167	0.385***	–0.016	0.200*	0.367***	0.206*	0.046
nUSEq	0.324***	0.289***	0.081	0.145	0.444***	–0.023	0.221**	0.394***	0.215*	–0.014
Comm	0.225**	0.139	0.042	0.039	0.261**	–0.036	0.323***	0.353***	0.011	–0.021
REITs	0.568***	0.404***	0.315***	0.314***	0.501***	0.257**	0.493***	0.602***	0.421***	0.248**

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

To see how optimal portfolio allocations can vary by industry-specific human capital, we performed a series of portfolio optimizations. For these optimizations, we assumed human capital to be 80% of the person's total wealth, where the only other asset is financial wealth (i.e., the completion portfolio represents the remaining 20% of the person's wealth). This simplifying assumption that the individual holds only two assets isolates the marginal impact of the various industry-specific forms of human capital on the optimal portfolio weights (more-complex scenarios that include multiple assets are discussed later, in the section on total wealth analysis). The individual is assumed to be 45 years old for all human capital calculations in this section.

The optimal portfolio allocations are reported in **Table 5**. In addition to the industry-specific human capital–optimized portfolios, the optimized portfolio that ignores total wealth (the island portfolio) is included for reference purposes. The optimal island portfolio, which is the same across all scenarios, is determined by using the same optimization procedure as for the total wealth portfolios, but it ignores the other dimensions of wealth (e.g., human capital, housing wealth, and pension wealth).

Table 5 provides a number of interesting insights. First, REITs is the only asset class that receives no allocation in any of the total wealth optimizations—probably because of the relatively high correlation between industry-specific human capital and REITs. The allocations are relatively similar across the various industries, with the majority having higher allocations to large growth, small value, and commodities. This finding suggests that there are risk factors common to investors' human capital across industries. Second, long-term bonds exhibit the largest variability in allocation as measured by the standard deviation of weights (9.0%), suggesting that the varying exposure to the bond risk factor is a key differentiator across industries. There are also notable differences among the industry-specific human capital portfolios that are related to an industry's inherent risks. For example, the finance portfolio has a lower allocation to large value, and the mining portfolio has a lower allocation to commodities. Overall, the allocations for the industry-specific human capital portfolios differ materially from those of the island portfolio, with an average absolute difference between the average industry-specific human capital portfolio and the island portfolio of 37.6%.

Human Capital Optimizations with Industry Asset Classes

The majority of prior research on the implications of industry-specific human capital for portfolio allocations has used an investment opportunity set that is based on equity industries (e.g., Eiling 2013), as opposed to the more generic asset classes in the previous section. Following prior research, we performed the same analysis as in the previous section for 11 industry equity portfolios obtained from Kenneth French's website.[1] The 11 industry portfolio names are Consumer NonDurables (NoDur); Consumer Durables (Durbl); Manufacturing (Manuf); Oil, Gas, and Coal Extraction and Products (Enrgy); Chemicals and Allied Products (Chems); Business Equipment (BusEq); Telecommunications (Telcm); Utilities (Utils); Wholesale, Retail, and Some Services (Shops); Healthcare, Medical Equipment, and Drugs (Hlth); and Finance (Money). Note that we excluded the "Other" industry portfolio from our analysis because it is not generally investable. The results of the optimizations, including those for the island portfolio, are shown in **Table 6**.

Table 5. Optimal Portfolio Allocations for Industry-Specific Human Capital Using Primary Asset Classes

	Asset Class												
	Cash	IntBd	LgBd	TIPS	HiYld	nUSBd	LarGro	LarVal	SmGro	SmVal	nUSEq	Comm	REITs
Construction	0.0%	14.8%	20.0%	19.4%	2.1%	12.6%	7.0%	1.3%	2.7%	20.0%	0.0%	0.0%	0.0%
Finance	8.4	8.6	4.2	20.0	6.8	3.0	13.8	0.0	9.5	20.0	0.0	5.8	0.0
Government	14.9	4.2	0.0	20.0	0.0	0.0	16.4	1.8	16.1	20.0	0.0	6.5	0.0
Health care	7.1	8.3	0.8	20.0	3.8	6.7	8.4	14.3	0.0	20.0	0.0	10.5	0.0
Lodging	0.0	14.1	20.0	16.6	2.7	13.7	2.6	7.0	0.0	20.0	0.0	3.5	0.0
Manufacturing	17.8	0.0	0.0	12.0	3.3	0.0	20.0	0.0	16.3	20.0	0.0	10.5	0.0
Mining	1.3	17.2	20.0	20.0	0.0	5.4	18.1	0.0	0.0	18.0	0.0	0.0	0.0
Real estate	1.5	14.1	20.0	16.9	1.7	13.1	7.2	3.8	1.7	20.0	0.0	0.0	0.0
Transportation	0.5	11.0	9.3	20.0	7.0	5.9	10.0	0.0	2.7	20.0	0.0	13.6	0.0
Utilities	10.2	5.7	0.0	16.5	0.0	3.9	20.0	0.0	9.9	20.0	2.6	11.2	0.0
Average	6.2	9.8	9.4	18.1	2.7	6.4	12.4	2.8	5.9	19.8	0.3	6.2	0.0
Std. dev.	6.2	5.2	9.0	2.5	2.4	4.9	5.8	4.4	6.2	0.6	0.8	4.9	0.0
Island portfolio	0.0%	17.1%	20.0%	20.0%	8.7%	8.3%	1.2%	3.5%	0.0%	14.8%	0.0%	0.0%	6.4%

Table 6. Optimal Portfolio Allocations for Various Industries Using Industry Portfolios

	Asset Class										
	NoDur	Durbl	Manuf	Enrgy	Chems	BusEq	Telcm	Utils	Shops	Hlth	Money
Construction	15.7%	0.0%	0.0%	9.7%	8.5%	0.0%	17.7%	13.3%	15.2%	20.0%	0.0%
Finance	16.2	0.0	0.0	8.3	14.1	0.0	14.4	12.4	20.0	14.7	0.0
Government	15.3	0.0	0.8	11.5	14.3	0.0	20.0	5.9	20.0	12.2	0.0
Health care	10.4	0.0	0.0	19.3	9.2	0.0	20.0	20.0	9.8	11.2	0.0
Lodging	13.4	0.0	0.0	12.6	8.7	0.0	19.3	19.6	6.5	20.0	0.0
Manufacturing	17.9	1.9	0.0	3.3	20.0	0.0	18.1	0.0	20.0	18.8	0.0
Mining	15.6	0.0	0.8	0.0	12.0	5.0	14.9	11.7	20.0	20.0	0.1
Real estate	20.0	0.0	0.0	6.0	7.1	0.0	13.1	13.8	20.0	20.0	0.0
Transportation	20.0	0.0	0.0	9.1	5.8	0.0	12.9	20.0	14.5	17.7	0.0
Utilities	20.0	0.0	0.0	0.5	20.0	0.6	15.4	4.8	20.0	18.7	0.0
Average	16.4	0.2	0.2	8.0	12.0	0.6	16.6	12.1	16.6	17.3	0.0
Std. dev.	3.0	0.6	0.3	5.6	4.8	1.5	2.6	6.5	4.7	3.2	0.0
Island portfolio	20.0%	0.0%	0.0%	3.7%	9.0%	0.0%	8.7%	20.0%	18.6%	20.0%	0.0%

The optimal portfolio allocations for the various industry-specific types of human capital are more alike for the industry portfolios (Table 6) than for the generic asset classes (Table 5). This finding can be attributed to the lower average absolute correlation between industry-specific human capital and the industry portfolios (Appendix A). The average absolute correlation between industry-specific human capital and the industry portfolios is 0.164, which is significantly less than the average absolute correlation between industry-specific human capital and the primary asset classes of 0.266, discussed in the previous section. The fact that industry-specific human capital is more correlated with fixed-income asset classes (Table 4)—and the fact that the industry portfolios in this section contain only equities—probably explains the comparatively smaller impact of human capital on the optimization results.

The health care industry portfolio has the highest average weight across the various industry-specific forms of human capital, whereas the utilities industry portfolio exhibits the highest variability for the industry-specific forms of human capital, with a standard deviation of weights of 6.5%. Some of the observed differences in optimal industry-specific human capital portfolios can be linked to shared risks between industry-specific human capital and its respective equity industry. For instance, the mining portfolio has a lower allocation to energy, the utilities portfolio has a lower allocation to utilities, and the health care portfolio has a lower allocation to health care. On average, industry-specific human capital portfolios formed on equity industries have an average absolute difference in optimal weights relative to the island portfolio of 18.3%.

How Risky Is Industry-Specific Human Capital?

The results in the previous section demonstrate that industry-specific human capital has a material impact on the optimal allocation for an investor's financial assets when incorporated into a portfolio optimization routine. Therefore, understanding the relative risks of the various industry-specific types of human capital is an important consideration when building portfolios.

To gain further insight into how the risk of human capital varies by industry, we used the five-factor model introduced by Fama and French (1993) to analyze the systematic risks associated with industry-specific human capital. The regression model with three equity and two bond factors is notated as follows:

$$\begin{aligned} R_{HC} - R_f = {} & \alpha + B_1\left(R_{Mkt} - R_f\right) + B_2\left(SMB\right) \\ & + B_3\left(HML\right) + B_4\left(TERM\right) \\ & + B_5\left(DEF\right) + \varepsilon. \end{aligned} \tag{4}$$

The regression coefficients measure the extent to which human capital is related to a given factor. Notably, the first coefficient (B_1) on the equity market factor measures whether industry-specific human capital is a "stock" or a "bond" in the spirit of Moshe Milevsky's 2012 book *Are You a Stock or a Bond? Create Your Own Pension Plan for a Secure Financial Future*.

Table 7 reports the coefficients from the regression (using Equation 4) for each of the 10 different types of human capital for a 45-year-old.

The coefficient for equity market risk (β_1 in Table 7) clearly varies by industry. For example, the coefficient is 0.05 for government industry–specific human capital, whereas the coefficient is 0.46 for lodging industry–specific human capital. Considered in isolation, this finding suggests that lodging industry–specific human capital is, for example, more "stock-like" than government industry–specific human capital. The average coefficient is significant (0.26), which suggests that human capital is approximately 25% stock-like and 75% bond-like. Although SMB (β_2) is not significant, HML (β_3) has a significantly positive loading on human capital for all but one industry. The finding that the return on human capital is positively related to the value factor (HML) has interesting implications for the asset pricing literature. It is consistent with the risk-based explanation of the value premium proposed by Fama and French (1996), suggesting that HML captures a hedging concern specific to the industry of an investor's human capital. In addition, industry-specific human capital has a significant positive relationship with the two bond factors—term and default. The positive loading on the term premium (β_4) is consistent with the long-duration nature of the human capital payoff, whereas the positive loading on the default factor, which is correlated with the equity market factor (β_1), suggests that human capital is related to credit risk. Finally, the regression R^2 values vary between 23% (lodging) and 59% (finance), highlighting the varying degree of idiosyncratic risk associated with industry-specific human capital.

The risk exposures of industry-specific human capital in Table 7 have important implications for an investor's optimal portfolio choice. For instance, an investor determining the optimal allocation to equity needs to consider the equity beta of the human capital of her employment industry. Given the results in Table 7, an investor working in the real

Table 7. Five-Factor Regression Coefficients for Various Industry-Specific Forms of Human Capital

	Industry-Specific Human Capital										
	Construction	Finance	Government	Health Care	Lodging	Manufacturing	Mining	Real Estate	Transportation	Utilities	Average
α	–0.51	–0.66	–0.56	–0.65	–0.40	–1.19**	0.23	–0.36	–0.71	–0.92*	–0.57***
β_1	0.39***	0.22**	0.05	0.29***	0.46***	0.12*	0.28***	0.40***	0.25***	0.14**	0.26***
β_2	–0.06	–0.01	–0.03	0.17	0.30	0.04	–0.15	0.04	0.04	0.02	0.03
β_3	0.41***	0.30***	0.12*	0.20*	0.20	0.18**	0.38***	0.46***	0.20**	0.20***	0.26***
β_4	0.43***	1.11***	0.71***	0.75***	0.40*	0.81***	0.35**	0.35*	0.61***	0.57***	0.61***
β_5	0.41	1.57***	0.92***	0.11	0.36	0.40**	0.09	0.53	0.25	0.16	0.48***
R^2	29%	59%	56%	33%	23%	53%	25%	25%	37%	39%	38%

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

estate industry should choose a more conservative portfolio with a lower equity exposure than an investor working for the government, holding all other variables constant.

The inverse relation between equity beta and optimal equity allocation is evident if we run a regression of the market beta coefficients in Table 7 on the resulting equity allocations in Table 5. The results are depicted in **Figure 1**.

The optimal allocation to equities is clearly affected by the riskiness of the industry-specific human capital: industry-specific human capital that is more bond-like (e.g., government) tends to have a higher equity allocation than industry-specific human capital that is more stock-like (e.g., lodging).

Pension Wealth

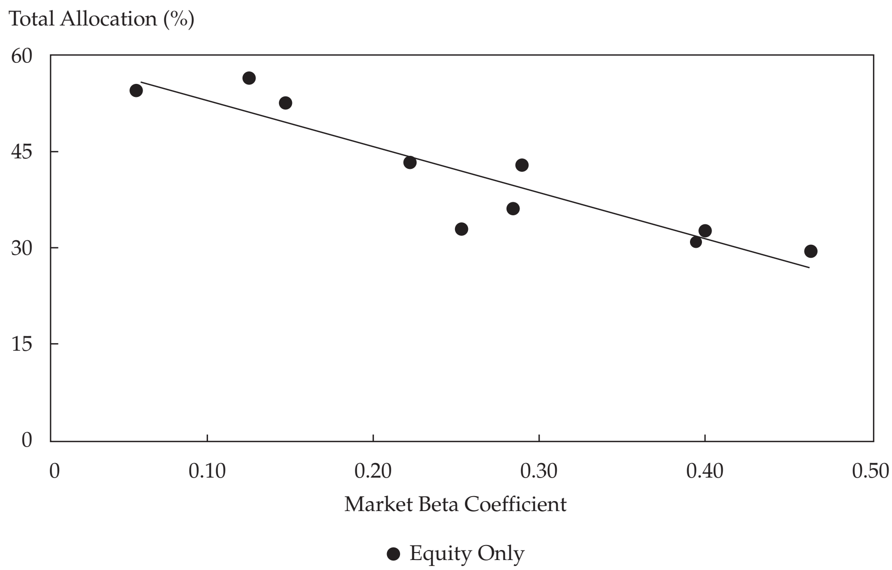
Pension wealth, defined here as the present value of a person's future US Social Security benefits, is a bond-like asset because the future Social Security income stream is fixed and guaranteed by the government. Our approach to estimating the present value of Social Security retirement benefits is similar to the one used for human capital, where pension wealth is the mortality-weighted net present value of Social Security benefits. Although we did not analyze the impact on the optimal portfolio of including pension wealth, we studied the implications of varying levels of pension wealth over an investor's lifespan in our total wealth analysis, discussed later in the article.

Pensions represent a significant asset for many in the United States, especially for older individuals: 9 out of 10 people age 65 and older receive Social Security benefits, and the average monthly benefit is $1,269 (based on data from the Social Security Administration website). And among elderly Social Security beneficiaries, 53% of married couples and 74% of unmarried persons receive at least 50% of their income from Social Security. Defined benefit pensions also represent a material asset for many Americans; however, the relative share of wealth for defined benefit plans has been declining as they become less popular among nongovernmental plan sponsors. Thus, for the purposes of our study, we considered pension benefits to be those promised by Social Security only.

Earlier we introduced a valuation model for human capital (Equation 3) that did not include pension benefits, such as Social Security retirement benefits. Excluding Social Security retirement benefits from human capital assumes that they are independent. This is a simplifying assumption, because pension benefits are wage based and thus related to human capital. However, the risk factors associated with pension benefits are different from those associated with human capital, and the relation between human capital and pension benefits varies by individual.

Accrued pension benefits are earned and thus, by definition, are less risky than future, yet-to-be-earned human capital. Although the amount of the pension benefit or the time at which pension benefits may commence may change (reducing the present

Figure 1. Relationship between Market Beta Coefficients and Optimal Equity Allocation by Industry-Specific Human Capital



value and affecting the discount rate), the riskiness associated with accrued pensions is not the same as the riskiness of human capital. For example, a change in wages would probably have a less material impact on the value of pension benefits for an older person (because Social Security retirement benefits are based on the highest average 35 years of inflation-adjusted earnings) than for a younger person. Also, married persons may be entitled to Social Security benefits that are based on the earnings record of their spouse; thus, their pension benefits are not necessarily based on their own human capital at all.

We estimated the total value of pension wealth by using the following equation:

$$P_t = \sum_n^D \frac{q_{D-n} SS_t \left(1+i_t\right)^{D-n}}{\left(1+rf_t\right)^{D-n}}. \quad (5)$$

This approach is functionally similar to Equation 3, where pension wealth P_t is the mortality-weighted net present value of future expected Social Security retirement benefits (SS_t). The key difference between Equation 5 (which estimates the value of pension wealth) and Equation 3 (which estimates the value of human capital) is that Equation 5 includes a risk-free rate (*rf*), which is assumed to be the return on long-term government bonds. Social Security retirement benefits (*SS*) are not assumed to commence until retirement (age 65), and the probability of being alive to receive the benefits is considered up to age 115 (*D*).

Jennings and Reichenstein (2001) proposed an alternative potential real discount rate for Social Security retirement benefits, which is the yield on TIPS; however, TIPS were not created until 1997, which is after the start of our analysis period. In reality, though, the discount rate for pension benefits should vary according to the amount of time until pension benefits commence (and are to be received) as well as the type of benefits. Using a single discount rate is a simplifying assumption for this analysis that may not be appropriate for all people or pensions.

Housing Wealth

We then incorporated regional housing wealth into the total wealth framework and found that including housing wealth leads to average absolute differences in optimal weights of 13.5% relative to the island portfolio. The observed portfolio impact is lower than that of industry-specific human capital because changes in region-specific home prices (based on the home price index for 10 US cities) are less correlated with the primary asset classes than with human capital.

Housing is a material asset for many Americans. According to the US Census Bureau, homeownership in the United States was 65.3% as of the third quarter of 2013 and has ranged between approximately 63% and 69% since 1965. According to summary data from the 2010 Survey of Consumer Finances, the primary residence represented 47.4% of all nonfinancial assets for a household and 29.43% of total assets. We defined housing wealth as the net equity value of the home, which is the value of the home minus all outstanding loans. Similar to the perspective of this article, Reichenstein and Delaney (1995) advocated accounting for a mortgage as a short bond position to reflect investors' full balance sheet of assets and liabilities as well as the properties of a mortgage as a fixed-income security.

In the region-specific housing analysis that we conducted, which is similar to our industry-specific analysis, we considered the marginal impact of including housing wealth in a portfolio optimization. We assumed the relative weights of housing wealth and financial assets to be equal, where both represent 50% of the total wealth. We assumed the net equity to be 50% of the home value. Although related studies have focused on the optimal portfolio weight of housing in an investor's total portfolio (e.g., Flavin and Yamashita 2002, 2011), we focused our analysis on optimizing financial assets, holding the relative portfolio weights of housing and financial assets constant.

We based the risk associated with housing wealth on the changes in different S&P/Case-Shiller Home Price indexes for 10 cities, with data obtained from the Federal Reserve Bank of St. Louis. We selected the following 10 cities for our analysis: Atlanta; Charlotte, North Carolina; Cleveland; Washington, DC; Las Vegas; Miami; Minneapolis; Phoenix; Seattle; and San Francisco. We used the term "regions" because the geographic region is the key distinguishing factor between the different changes in home values. Although we selected particular cities to represent different regions, states or other characteristics could have been used just as easily. The regions we selected were intended to be broadly representative of the United States. The optimization results for the region-specific housing portfolios are reported in **Table 8**. The correlations between region-specific housing wealth and the primary asset classes are shown in Appendix B.

The results in Table 8 suggest that although the impact of including housing wealth is smaller than that of human capital, housing wealth still has a material impact on the portfolio optimization results. Specifically, the average absolute difference between the region-specific housing portfolio and

Table 8. Impact of Region-Specific Housing on Optimal Portfolio Allocations

	Asset Class												
Region	Cash	IntBd	LgBd	TIPS	HiYld	nUSBd	LarGro	LarVal	SmGro	SmVal	nUSEq	Comm	REITs
Atlanta	0.0%	18.4%	20.0%	20.0%	5.6%	13.3%	1.2%	1.6%	0.0%	20.0%	0.0%	0.0%	0.0%
Charlotte	0.0	18.4	20.0	20.0	5.7	10.6	2.1	3.4	0.0	19.8	0.0	0.0	0.0
Cleveland	0.0	19.8	20.0	20.0	6.5	12.7	0.0	0.5	0.0	20.0	0.0	0.0	0.5
Washington	0.0	13.5	20.0	20.0	1.6	13.8	9.3	1.9	0.0	20.0	0.0	0.0	0.0
Las Vegas	0.0	3.9	20.0	20.0	20.0	17.3	0.0	0.0	0.0	18.7	0.0	0.0	0.2
Miami	0.0	6.2	20.0	20.0	9.6	17.0	10.2	0.0	0.0	17.0	0.0	0.0	0.0
Minneapolis	0.0	15.7	20.0	18.9	6.1	11.0	4.4	3.9	0.0	20.0	0.0	0.0	0.0
Phoenix	0.0	16.6	20.0	18.2	7.9	12.8	2.3	2.1	0.0	20.0	0.0	0.0	0.0
Seattle	0.0	16.3	20.0	19.9	7.9	13.9	0.5	1.5	0.0	20.0	0.0	0.0	0.0
San Francisco	0.0	14.8	20.0	18.0	6.7	14.2	3.9	2.4	0.0	20.0	0.0	0.0	0.0
Average	0.0	14.4	20.0	19.5	7.8	13.6	3.4	1.7	0.0	19.6	0.0	0.0	0.1
Std. dev.	0.0	5.0	0.0	0.8	4.5	2.1	3.5	1.3	0.0	0.9	0.0	0.0	0.1
Island portfolio	0.0%	17.1%	20.0%	20.0%	8.7%	8.3%	1.2%	3.5%	0.0%	14.8%	0.0%	0.0%	6.4%

the island portfolio is 11.4%. In general, region-specific housing wealth portfolios have higher allocations to small value and lower allocations to REITs compared with the island portfolio. The latter impact is intuitive given the natural link between REITs and housing wealth. Overall, the lower impact of housing wealth on the optimization results can be attributed to the lower average correlation between housing wealth and financial assets (0.170, versus 0.266 for the industry-specific human capital).

Interestingly, our recommendation here runs counter to the well-documented phenomenon that investors tend to invest in assets close to home, known as the "home bias puzzle" (see Coval and Moskowitz 1999). The region-specific housing portfolios will underweight (overweight) assets that have a high (low) correlation with region-specific housing wealth relative to the island portfolio. Thus, to the extent that housing prices are positively correlated with local securities (e.g., the stock price of companies based in a given region), the total wealth optimizations will underweight these "local" assets.

Total Wealth Analysis

Changes in the composition of total wealth over the lifespan of an investor have a significant impact on the optimal portfolio, with the optimal equity allocation decreasing from 61% at age 25 to 26.2% at age 65. The depletion of human capital over the lifespan is a key driver of the changes in the optimal equity allocation.

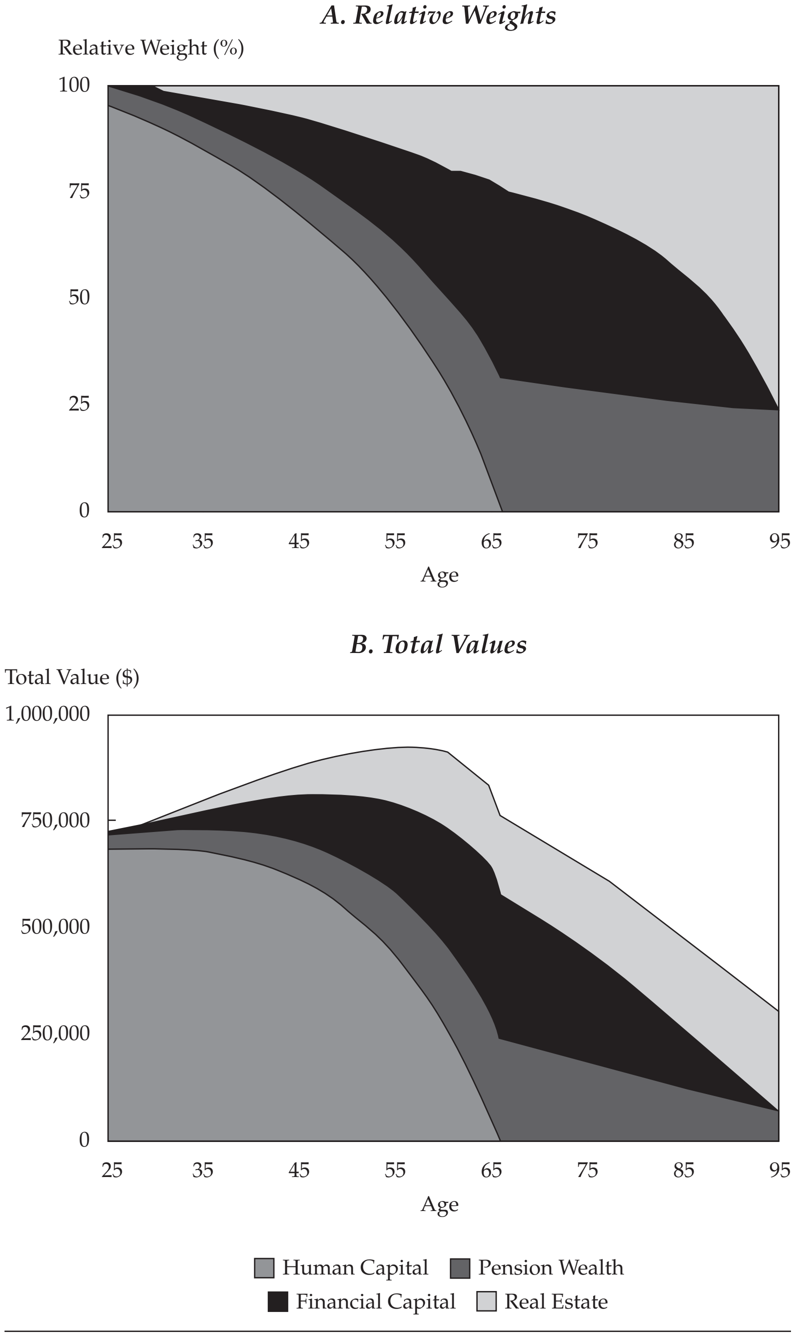
Our earlier optimizations demonstrated that meaningful differences can result in a portfolio optimization that includes assets beyond just financial wealth. At this point in our study, we took a more holistic perspective of wealth by including all four types of nonfinancial wealth in the analysis.

It is important to understand how the relative weights of different types of wealth are likely to vary over a person's lifetime. To demonstrate this relationship, we created a hypothetical scenario that begins with a 25-year-old who earns $40,000 a year in after-tax income. The person's real annual wage growth rate is expected to be a constant 1%, the annual savings rate is 10%, the discount rate is 8%, and the rate of expected inflation is 3%. We further assume that the person purchases a home costing $100,000 at age 30. The home is purchased with a 10% down payment (which comes from financial capital), with the remainder financed by a 30-year mortgage at an interest rate of 5%. The real growth rate of the home is assumed to be 1%. Social Security retirement benefits are assumed to be $20,000 a year (in today's dollars), commencing at age 65, and the real discount rate for Social Security retirement benefits is 5%. This person's total wealth is depicted in **Figure 2**.

Although our hypothetical scenario is based on a set of relatively precise assumptions about a certain individual's total wealth over his lifespan, a number of the trends in Figure 2 can be generalized for the average investor:

- Human capital is likely to be the dominant asset for younger people, those in their 20s and 30s.
- The relative value of pensions increases as a person nears retirement.
- Financial assets are likely to be at their largest at retirement.
- The relative value of real estate is likely to increase over a person's lifetime, assuming housing wealth is not used to fund retirement.

Figure 2. Hypothetical Depiction of the Relative Weights and Values of Different Assets over an Individual's Lifetime



On the basis of the hypothetical scenario in Figure 2, we considered 10 points across the lifespan, from ages 25 to 70. **Table 9** shows the relative weights of the total wealth components at each age.

For each total wealth decomposition in Table 9, we ran an optimization for the 10 industry-specific types of human capital and the 10 region-specific types of housing wealth (i.e., 100 combinations for each age) and then computed the average optimal weights by age. We ran a total of 1,000 optimizations. Although this approach treats employment industry and state of residence as independent variables, which is unlikely to be the case in reality, it allowed us to isolate the average impact by age. **Table 10** contains the average optimal allocations for the various age groups.

Table 10 highlights the significant impact of the composition of total wealth by assumed age on the optimal asset allocation, suggesting that the optimal equity allocation decreases with age. Specifically, the results provide evidence in favor of an equity "glide

Table 9. Total Wealth Breakdown by Age

	Assumed Age									
	25	30	35	40	45	50	55	60	65	70
Human capital	94%	91%	85%	78%	70%	60%	48%	31%	7%	0%
Housing wealth	4	5	7	8	10	12	16	20	30	31
Pension wealth	1	2	5	9	12	17	22	29	41	43
Financial capital	1	1	3	5	8	11	14	19	22	27
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Housing equity	0%	10%	21%	34%	48%	63%	80%	100%	100%	100%
Implied leverage	na	10.00	4.65	2.95	2.10	1.59	1.25	1.00	1.00	1.00

na = not applicable.

Table 10. Average Optimal Allocations by Age

	Assumed Age												
	25	30	35	40	45	50	55	60	65	70	Average	Std. Dev.	Slope
Cash	13.2%	12.1%	10.0%	7.5%	5.8%	2.6%	0.0%	0.0%	0.0%	0.0%	5.1%	5.0%	–0.3%
IntBd	5.3	6.3	9.3	10.6	11.8	14.9	16.7	17.6	18.2	15.5	12.6	4.4	0.3
LgBd	1.8	2.8	5.4	8.0	12.8	16.2	20.0	20.0	20.0	20.0	12.7	7.2	0.5
TIPS	16.0	17.1	18.1	18.6	19.1	19.9	19.8	20.0	20.0	17.1	18.6	1.4	0.1
HiYld	0.2	0.0	0.7	2.1	0.4	4.1	4.3	2.6	6.0	0.9	2.1	2.0	0.1
nUSBd	2.6	3.2	5.4	5.1	8.4	8.0	11.1	11.8	9.5	17.7	8.3	4.3	0.3
LarGro	17.2	16.5	15.2	13.3	14.3	7.9	2.7	1.2	0.4	1.2	9.0	6.7	–0.4
LarVal	2.4	1.5	2.5	2.6	2.0	2.9	2.8	3.1	2.1	2.6	2.5	0.5	0.0
SmGro	12.8	13.5	10.5	7.7	5.8	3.1	0.2	0.0	0.0	0.0	5.3	5.2	–0.3
SmVal	20.0	19.9	20.0	20.0	19.4	19.9	20.0	19.9	18.8	20.0	19.8	0.4	0.0
nUSEq	0.6	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0
Comm	8.0	6.9	2.9	4.4	0.3	0.5	0.0	0.0	0.0	0.0	2.3	3.0	–0.2
REITs	0.0	0.0	0.0	0.0	0.0	0.1	2.3	3.8	5.0	5.1	1.6	2.1	0.1
Equity	61.0%	58.5%	51.2%	47.9%	41.8%	34.4%	28.0%	28.1%	26.2%	28.9%			

path," which refers to the decreasing equity weight of target-maturity funds, given the reduction in the optimal equity allocation from 61.0% at age 25 to 26.2% at age 65. The observed decrease in equity allocation is monotonic between the ages of 25 and 55 as the weight of human capital in the total wealth portfolio decreases from 94% to 48%, highlighting the important impact of human capital on optimal portfolio weights. Long-term bonds exhibit the most significant variation in weights (with a standard deviation of 7.2%), increasing monotonically from 1.8% at age 25 to the maximum weight of 20.0% at age 55.

The Alpha Benefit of a Total Wealth Perspective

Our total wealth approach led to an average annual increase in risk-adjusted alpha of 30 bps across 1,000 scenarios studied. However, the alphas varied considerably by industry-specific human capital and generally decreased by age as the share of human capital diminished.

In studying the potential alpha benefit of a total wealth approach, we determined the alpha by solving for the increase in the return on the island portfolio, which leads to the same Sharpe ratio as that of the total wealth portfolios. The average annualized alphas by various industry-specific types of human capital, region-specific housing, and age are shown in **Table 11**. Manufacturing and government boast the highest alphas among industries, and younger employees benefit from higher alphas more than older ones do. Regionally, there is little spread between the highest-alpha cities (Charlotte and Cleveland, at 32 bps) and the lowest-alpha ones (Phoenix and Las Vegas, at 26 bps and 25 bps, respectively). Less risky regions, however, posted higher alphas than did riskier ones. Overall, these findings suggest that those whose total wealth is dominated by nonfinancial assets, such as human capital, have the most to gain from a total wealth approach to portfolio optimization.

Table 11. The Alpha Benefit of a Total Wealth Perspective

	Alpha
Industry	
Construction	0.12%
Finance	0.18
Government	0.57
Health care	0.14
Lodging	0.04
Manufacturing	0.70
Mining	0.25
Real estate	0.12
Transportation	0.21
Utilities	0.64
Average	0.30
Standard deviation	0.23
Region	
Atlanta	0.31%
Charlotte	0.32
Cleveland	0.32
Washington	0.31
Las Vegas	0.25
Miami	0.28
Minneapolis	0.31
Phoenix	0.26
Seattle	0.31
San Francisco	0.28
Average	0.30
Standard deviation	0.02
Age	
25	0.45%
30	0.38
35	0.40
40	0.40
45	0.41
50	0.31
55	0.12
60	0.13
65	0.14
70	0.20
Average	0.30
Standard deviation	0.12

Conclusion

In our study, we explored the implications of taking a total wealth perspective for optimal asset allocations. We included in our portfolio optimization not only financial assets but also industry-specific human capital, region-specific housing wealth, and pension wealth. We treated the financial assets as a "completion portfolio," optimized to minimize the variance in inflation-adjusted change of an investor's total wealth. We found significant differences in the optimal allocation for an investor's wealth when outside assets are included, with the largest differences occurring when nonfinancial assets (e.g., human capital) are the dominant assets from a total wealth perspective.

We demonstrated that incorporating nonfinancial assets—specifically, industry-specific human capital, region-specific homeownership, and pension benefits—into a portfolio optimization routine results in portfolios with significant variations. These portfolios vary both from their traditional counterparts (optimized on the basis of financial assets only) and within the diverse ways total wealth is composed (e.g., various industry-specific forms of human capital). Taken together, these results suggest that a total wealth approach is necessary to build truly efficient portfolios.

Our findings have important practical implications for how investment professionals should think about building portfolios. Although replicating the exact methodology used in our study might prove impractical, the implications of the total wealth framework can be approximated by using simplifying assumptions. For instance, the relative riskiness of different employment industries and their correlations with financial assets—a key subject of our study—can be approximated by using publicly available historical wage data by industry (e.g., for the United States, one can obtain data from the Bureau of Labor Statistics or the Bureau of Economic Analysis).

Retirement plans, particularly industry-specific target-date funds, are another area of potential application for the total wealth framework. Today, most target-date funds are created on the basis of average demographic information. As documented in our study, however, workers in a given employment industry are exposed to particular risks. Thus, the total wealth framework can be used to develop a glide path that recognizes the riskiness of a given employment industry. Finally, this methodology can be extended to other types of investors, such as charitable endowments, because every investor is exposed to risks that extend beyond the financial asset portfolio.

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Appendix A. Correlations between Human Capital and Industry Portfolios

The correlations between industry-specific human capital and industry portfolios are shown in **Table A1**.

Table A1. Correlations between Industry-Specific Human Capital and Industry Portfolios, Q2 1993–Q1 2013

	Industry-Specific Human Capital									
Industry Portfolio	Construction	Finance	Government	Health Care	Lodging	Manufacturing	Mining	Real Estate	Transportation	Utilities
NoDur	0.247**	0.106	–0.004	0.119	0.273**	–0.060	0.131	0.263**	0.109	0.004
Durbl	0.357***	0.260**	0.022	0.125	0.457***	–0.080	0.199*	0.420***	0.206*	–0.016
Manuf	0.307***	0.210*	–0.027	0.104	0.404***	–0.099	0.178	0.359***	0.162	–0.076
Enrgy	0.175	0.103	–0.036	–0.018	0.214*	–0.092	0.283**	0.259**	–0.013	–0.015
Chems	0.265**	0.100	–0.027	0.093	0.289***	–0.126	0.157	0.303***	0.112	–0.091
BusEq	0.144	0.035	–0.094	0.034	0.330***	–0.164	–0.020	0.162	0.063	–0.142
Telcm	0.203*	0.198*	0.032	0.035	0.251**	0.000	0.160	0.183	0.144	0.092
Utils	0.269**	0.265**	0.207*	0.169	0.291***	0.150	0.301***	0.295***	0.183	0.270**
Shops	0.192*	0.055	–0.095	0.116	0.311***	–0.182	0.001	0.194*	0.103	–0.091
Hlth	0.195*	0.115	0.040	0.089	0.179	–0.063	0.031	0.190*	0.102	0.011
Money	0.409***	0.324***	0.142	0.200*	0.426***	0.060	0.253**	0.432***	0.279**	0.063
Other	0.260**	0.165	–0.032	0.117	0.372***	–0.122	0.137	0.282**	0.138	–0.042

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

Appendix B. Correlations between Housing Wealth and Asset Classes

The correlations between region-specific housing wealth and the primary asset classes are shown in **Table B1**.

Table B1. Correlations between Region-Specific Real Estate and Primary Asset Classes, Q2 1993–Q1 2013

	Region-Specific Real Estate									
Asset Class	Atlanta	Charlotte	Cleveland	Washington	Las Vegas	Miami	Minneapolis	Phoenix	Seattle	San Francisco
Cash	0.195*	0.094	0.266**	–0.117	–0.029	–0.018	0.099	0.007	0.244**	0.031
IntBd	–0.110	–0.068	–0.164	–0.049	–0.160	–0.063	0.074	–0.118	–0.149	–0.060
LgBd	–0.165	–0.069	–0.194*	0.008	–0.091	0.034	0.141	0.013	–0.141	0.003
TIPS	0.000	–0.037	–0.014	0.131	–0.054	0.020	0.098	0.009	0.014	0.118
HiYld	0.260**	0.244**	0.219*	0.225**	0.149	0.191*	0.280**	0.291***	0.174	0.297***
nUSBd	–0.094	–0.020	–0.128	–0.057	–0.077	–0.050	0.047	–0.071	–0.158	–0.083
LarGro	0.148	0.095	0.210*	0.012	0.158	0.074	0.093	0.215*	0.146	0.153
LarVal	0.249**	0.182	0.246**	0.158	0.307***	0.256**	0.203*	0.352***	0.245**	0.296***
SmGro	0.186*	0.127	0.208*	0.088	0.183	0.132	0.125	0.209*	0.133	0.151
SmVal	0.231**	0.176	0.185	0.206*	0.304***	0.264**	0.198*	0.305***	0.211*	0.272**
nUSEq	0.243**	0.180	0.261**	0.194*	0.261**	0.250**	0.221**	0.328***	0.245**	0.316***
Comm	0.198*	0.105	0.245**	0.188*	0.213*	0.159	0.149	0.217*	0.164	0.274**
REITs	0.294***	0.294***	0.233**	0.334***	0.330***	0.372***	0.383***	0.422***	0.300***	0.386***

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

Notes

1. See http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

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