

The Euro as a Reserve Currency for Global Investors

Luis M. Viceira¹ and Ricardo Gimeno

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¹Viceira: Harvard Business School, Boston MA 02163, CEPR and NBER. Email lviceira@hbs.edu. We are very grateful to Johnny Kang for extremely valuable research assistance, and to Rafael Repullo, Jaume Ventura, and participants in the Spain in the EMU Conference organized by the Banco de España for helpful comments and suggestions.

1 Introduction

Reserve currencies are traditionally defined as currencies held in significant quantities by central banks and other major financial institutions as part of their foreign exchange reserves. Under this definition, the euro has become one of the main reserve currencies in the world since its introduction in 1999, second only to the U.S. dollar. The euro represented 25.9% of worldwide official foreign exchange reserves in the first quarter of 2009, up from 18.3% in the last quarter of 2000. This growth has become mainly at the expense of the U.S. dollar which, although still represented 64.9% of worldwide official foreign exchange reserves in the first quarter of 2009, has seen its share of global reserves decline significantly from 71% in the last quarter of year 2000.²

The holding of certain currencies in significant quantities by central banks and major financial institutions reflects to a large extent a desire by households and firms to hold them. Accordingly, understanding the factors driving household demand for currencies can help explain what makes a currency into a reserve currency. One important driver of currency demand is transactions. Many goods and services traded at a global scale such as oil are typically priced in certain currencies, particularly the U.S. dollar. This results in a desire by households and firms to hold those currencies to facilitate their current and future transactions of these goods. This article argues that financial considerations can also be an important driver of the demand for currencies.

As financial assets, currencies are essentially investments in cash instruments. The return to a local investor from holding a foreign currency is equal to the short-term interest rate paid on that currency plus the change in the exchange rate between that currency and his own local currency. As with any other financial asset, investors demand foreign currencies must be driven by either speculative reasons or hedging—or risk management—reasons.

Speculative demand for specific currencies arises when investors expect high returns on those currencies in excess to the interest paid on their own currency. Speculative reasons are unlikely to be a main driver of stable demand for currencies. The empirical evidence about the long-term returns on the currencies of developed economies suggests that unconditional expected excess currency returns are close to zero; this makes them unattractive assets to hold for speculative reasons, at least on

²IMF Statistics Department COFER database and International Financial Statistics.

a long-term basis (Campbell, Serfaty-de Medeiros, and Viceira, 2010). The existing evidence that the currencies of developed economies with high short-term interest rates tend to appreciate, while the currencies of developed economies with low short-term interest rates tend to depreciate,³ provides some basis for holding currencies for speculative reasons, but only on a short-term basis. The currency trading strategy implied by this empirical phenomenon known as “carry trade” calls not for holding stable long positions in certain currencies, but rather for holding actively managed currency portfolios whose long positions vary with interest rates (Burnside, Eichenbaum, and Rebelo (2007), Brunnermeier, Nagel, and Pedersen (2009)). The recent financial crisis has also provided a painful reminder that this is a risky strategy whose returns can reverse very quickly, causing important losses to investors.

A more promising venue for generating stable long-term demand for currencies is risk management. Currencies can help investors manage portfolio risk. First, currencies can help conservative investors seeking to minimize overall portfolio risk or consumption risk. A well-known result in dynamic portfolio choice is that the optimal portfolio that minimizes risk is composed of local-currency inflation-indexed bonds matching the investor’s consumption horizon. Inflation-indexed bonds help investors minimize risk because they help investors hedge real interest rate risk and inflation risk (Campbell and Viceira 2001, 2002; Brennan and Xia 2002; Campbell, Chan, and Viceira 2003; Wachter 2003). However, local-currency inflation-indexed bonds are not always available to investors. An important question then is which assets best approximate the hedging properties of inflation-indexed bonds.

Nominal bonds denominated in local currency will be effective substitutes of inflation-indexed bonds only to the extent that local real interest rates and expected inflation are stable at the investor’s horizon. Otherwise, they might not be good substitutes, and bonds denominated in foreign currencies might help investors hedge real interest rate risk and inflation. For example, the presence of short-term inflation uncertainty makes short-term nominal bonds risky; in that case Adler and Dumas (1983) argue that portfolios of short-term bonds denominated in foreign currencies can help short-term investors minimize risk. However, this argument for holding foreign currencies is not likely to have significant practical relevance for investors in developed economies, as short-term inflation risk is generally small in these economies.

If real interest rates are not stable, local-currency short-term nominal bonds are

³This is known as the “forward premium puzzle” (Hansen and Hodrick (1980), Fama (1984), Hodrick (1987), Engel (1996)).

risky at long horizons, even if short-term inflation expectations are stable. They are risky because they expose investors to real interest rate risk—or reinvestment risk. Local-currency long-term nominal bonds can help investors hedge this risk, because they experiment capital gains when real interests fall. However, these bonds expose investors to long-term inflation risk, which can be significant in practice (Campbell and Viceira 2005). In that case, Campbell, Viceira and White (2003, CVW henceforth) argue that bonds denominated in foreign currencies with stable real interest rates can help long-term investors hedge real interest rate risk and inflation risk.

Second, currencies can also help less conservative investors who optimally hold portfolios of risky assets such as stocks or bonds to manage risk when the excess returns on certain currencies are negatively correlated with the returns on other assets. Campbell, Serfaty-de Medeiros, and Viceira (2010, CSV henceforth) argue that investors can reduce the overall volatility of their portfolios by investing in self-financing currency portfolios that effectively transform the currency exposure implicit in their portfolios of assets into exposure to the currencies whose returns are negatively correlated with the returns on those assets. Of course, if currency returns are largely uncorrelated with the returns on other assets, investors holding internationally diversified portfolios of equities and bonds should optimally avoid investing in foreign currencies by fully hedging the currency exposure implicit in their portfolios (Solnik 1974).

These arguments suggest a definition of a reserve currency from a risk management perspective. A reserve currency is one that investors demand either because it helps them hedge real interest rate risk and inflation risk, or because it helps them reduce the volatility of their portfolios of stocks and bonds because its return is negatively correlated with the returns on those assets. CVW find that empirically the U.S. dollar and the deutschemark and its successor the euro have been reserve currencies in the first sense. Interestingly, CSV find that these two currencies are also reserve currencies in the second sense. The evidence in CVW about the euro is limited because their sample period is mostly dominated by the deutschemark, while the evidence in CSV is more robust, because their sample period includes most of the existence of euro as a currency. This article re-examines the role of the euro as a reserve currency in the sense of CVW by revising and updating their evidence for the most recent period, and reviews the evidence in CSV in detail. Of course, this raises the important question of why in equilibrium certain currencies become reserve currencies in the risk management sense of CVW or CSV, while others do not. Hassan (2008) examines this question, and provides a rationale based on consumption risk.

This article also reviews these general equilibrium arguments.

Another area of focus of this article is the exploration of the role of the euro as a currency that promotes the integration of segmented capital markets and thus risk sharing among investors in the countries that have joined the European Monetary Union (EMU). In particular, it explores if stock markets in these countries have ceased to be priced locally, instead becoming priced at the level of the new currency area.

Prior research has already provided some evidence that the adoption of the euro has been conducive to capital market integration. De Santis and Gerard (2006) and Schoenmaker and Bosch (2008) document a strong decline in equity home bias after the introduction of the euro in 1999, and attribute this reduction to the emergence of institutional investors—such as mutual funds, pension funds, and life insurance companies—in Europe, whose assets tripled from 44% of GDP in 1985, to 122% of GDP in 2004. Interestingly, they also document a parallel increase in regional bias, or in the preference for euro stocks in detriment of stocks from other regions in the world. Consistent with this evidence, Ferreira and Ferreira (2006) document an increase in the relative importance of industry factors over country factors in euro markets over the period 1999-2001.

Hardouvelis, Malliaropulos, and Priestley (2006, HMP henceforth) estimate the conditional probability that the expected return on a member country stock market is priced by a euro zone CAPM. They model this probability as a function of forward interest rate differentials with Germany. They find evidence that the integration of national stock markets in the Euro zone was already occurring in the second half of the 1990s, as measured by an increase in the conditional probability over time that parallels the reduction in forward rate differentials. Cappiello, Hördahl, Kadareja, and Manganelli (2006, CHKM henceforth) also examine the empirical evidence on capital markets integration using the Dynamic Conditional Correlation-GARCH model of Engle (2002). They find that the cross-sectional average of conditional correlations among euro capital markets increased over time during the period 1987-2005. They find strong evidence of integration of government bond markets but, in contrast to HMP, much weaker evidence of stock market integration.

This article also investigates if national stock markets in the euro area have become more integrated after the introduction of the euro. Our analysis adds to the existing evidence about stock market integration in two dimensions. First, we investigate whether stocks in the euro zone have moved from a regime in which national stock markets were priced with discount rates that were predominantly country specific, to

a regime in which national stock markets are predominantly priced by a EMU-wide common discount rate. Second, our sample period extends through late 2008; thus we consider almost nine years of existence of a common currency.

If expected stock excess returns are time varying, stock prices will move in response to either news about cash flows, or news about discount rates (Campbell 1991). As capital markets become integrated, we should expect discount rates to exhibit increased co-movement with a common EMU discount rate, while cash flows may or may not exhibit increased common variation, since they will be subject not only to common aggregate macroeconomic shocks, but also to regional, industry, and company specific shocks. We test this hypothesis by adapting the beta decomposition methodology of Campbell and Vuolteenaho (2004) and Campbell, Polk, and Vuolteenaho (2010) to an examination of capital integration.

This article is structured as follows. Section 2 examines the role of the euro as a reserve currency for conservative global investors. Section 3 examines the role of the euro for global equity investors. Section 4 examines whether the euro has promoted increased capital market integration among EMU members. Finally, Section 5 concludes.

2 The Euro As A Safe Currency

The conventional view on currencies states that holding foreign currencies is a risky investment. This view is rooted in the perception that real exchange rates are volatile and largely uncorrelated with the returns on other assets. In that case, investors should optimally hedge all foreign currency exposure implicit in their internationally diversified portfolios (Solnik, 1974). Indeed, Perold and Schulman (1988) and others find that full hedging of currency exposure can substantially reduce the short-term return volatility of internationally diversified portfolios of bonds and equities of US investors. However, recent research in Finance has challenged this view on both empirical and theoretical grounds.

A first challenge to the conventional view on currency hedge comes from examining empirically whether ex-ante real interest rates are constant over time as Fama (1975) famously asserted and, if they are not, whether currencies can play a role in helping investors hedge against unfavorable changes in future real interest rates. Recent em-

empirical research has estimated that real interest rates have been subject to persistent shocks since the 1970's in the U.S., which has resulted in statistically and economically significant real interest rate variation (Campbell and Viceira 2001, Campbell, Sunderan, and Viceira 2009). Inflation-indexed bonds, which several countries around the world have been issuing during the last two decades, provide direct evidence that ex-ante real interest rates move considerably over time (Campbell, Shiller, and Viceira 2009).

Time variation in real interest rates has important implications about what constitutes the minimum risk asset or portfolio of assets across investment horizons. Real interest rate risk makes investing in default-free short-term government bonds risky at long horizons, as the future rates of reinvestment of these bonds are uncertain.⁴ Long-term investors can avoid this risk by investing instead in a portfolio of long-dated inflation-indexed bonds matching the timing and horizon of their consumption plans (Campbell and Viceira 2001, 2002, Brennan and Xia 2002, Campbell, Chan, and Viceira 2003, Wachter 2003).

In the absence of inflation-indexed bonds available for investment, long-term conservative investors will seek to replicate the payoffs on the optimal portfolio of inflation-indexed bonds as best as they can out of existing assets available for investment. Campbell, Viceira, and White (2003) argue that currencies with historically low volatile real interest rates might help investors in countries with volatile real interest rates hedge real interest rate risk at home. Of course, this is only possible if real exchange rate risk between the home currency and the foreign currency does not overwhelm the lower real interest rate volatility of the foreign currency.

CVW explore this hypothesis using the long-term portfolio choice theory of Campbell, Chan, and Viceira (2003, CCV henceforth). This theory is itself an empirical implementation of Merton's (1969, 1971, 1973) portfolio choice theory with time-varying investment opportunities that assumes that the dynamics of asset returns and the state variables driving variation in risk premia, real interest rates, and inflation are described by a first-order vector autoregressive (VAR) structure. Under this assumption, CCV derive the optimal dynamic portfolio and consumption rules of an infinitely-lived investor with Epstein-Zin (1989, 1991) recursive preferences who lives

⁴These bonds can also be risky at short horizons when they are nominal, as it is typically the case. As such they are subject to short-run inflation risk. While this risk is typically very small in developed economies, it can be important in developing economies with highly volatile short-term inflation.

off financial wealth. CCV show that the optimal portfolio rule is linear in the VAR state vector.

Adapting CCV's model to the case in which risk premia are constant and only real interest rate varies over time, Campbell and Viceira (2002) show that the optimal portfolio rule α takes the following form:

$$\alpha = \frac{1}{\gamma} \Sigma^{-1} (\mathbf{E} \mathbf{x}_{t+1} + \sigma^2 / 2) + \left(1 - \frac{1}{\gamma}\right) \Sigma^{-1} \sigma_1 + \left(1 - \frac{1}{\gamma}\right) \Sigma^{-1} \sigma_h. \quad (1)$$

In equation (1) γ denotes the coefficient of relative risk aversion, \mathbf{x}_{t+1} denotes the vector of log returns in excess of the short-term interest rate, Σ denotes the variance-covariance matrix of excess returns, σ^2 denotes the vector of excess-return variances, the main diagonal of Σ , and σ_1 denotes the vector of covariances of each risky asset's excess return with the short-term interest rate. The vector σ_h contains the covariances of each excess return with revisions in expectations of future real interest rates:

$$\sigma_h \equiv \text{Cov}_t(\mathbf{x}_{t+1}, -(\mathbf{E}_{t+1} - \mathbf{E}_t) \sum_{j=1}^{\infty} \rho^j r_{1,t+1+j}). \quad (2)$$

Equation (1) shows that the optimal portfolio rule for the long-term investor has three components. The first two components describe an instantaneously mean-variance efficient portfolio demand, common to both long-term and short-term investors. This demand includes a speculative component based on the expected excess simple return on risky assets (or equivalently, expected excess log returns plus one-half their variance), and a global minimum variance component based on the short-term volatility of the optimal portfolio. Total short-term portfolio demand is a weighted average of these two components, with weights given by $1/\gamma$ —risk tolerance—and $1 - 1/\gamma$.

The third component in (1) is specific to long-term investors. This is Merton's intertemporal hedging demand, which is proportional to $1 - 1/\gamma$. This demand measures to what extent intertemporal considerations lead long-horizon investors to optimally choose portfolios that deviate from the portfolios that are optimal for short-term investors. In this particular case, long-term conservative investors with $\gamma > 1$ optimally tilt their portfolios toward assets whose returns covary positively with declines in revisions of expected future real interest rates.

CVW use the CCV model to explore the role of currencies in helping investors

hedge real interest rate risk. They consider four currencies—the US dollar, the British pound, the Japanese yen, and the euro and its predecessor the deutschemark—for the period going from the first quarter of 1973 through the fourth quarter of 2001. Specifically, they consider the problem of a long-term U.S. investor who is deciding how to allocate his wealth between US dollars and one of the other three currencies—i.e., between U.S. short-term government bonds and government bonds denominated in one of the other three currencies—. For symmetry, they also consider the problem of a long-term investor in each one of the other three currency areas who is deciding how to allocate his wealth between his domestic currency and US dollars.

For each pairing of the US dollar with the other three currencies, CVW estimate a VAR system that includes each currency’s ex post real interest rate and the real exchange rate, both of which are assumed to follow stationary processes. The real interest rate is the log three-month nominal short rate, less log realized inflation over the period, measured by the log change in the CPI. The log real exchange rate level is the log real foreign currency price of domestic currency, the sum of the log nominal exchange rate and the log domestic CPI, less the log foreign CPI. This system characterizes the dynamics of real interest rates and inflation for each currency pair. The VAR estimates are then used to compute and compare the optimal portfolio of the long-term US investor and the optimal portfolio of the long-term foreign investor.

This section develops an exercise similar to CVW, but taking the euro—and its predecessor the deutschemark—instead of the US dollar as the anchor currency. Thus we estimate three VAR systems, one that includes the US dollar and the euro, a second one that includes the pound and the euro, and a third one that includes the yen and the euro. The euro is always an investment in German short-term government bonds. We also extend CVW’s sample period, bringing our sample period from the first quarter of 1973 through the fourth quarter of 2005.

Table 1 reports optimal portfolio allocations to short-term bonds in each currency pair for Epstein-Zin investors with relative risk aversion coefficients of 1, 5, and 2000, and unit elasticity of intertemporal substitution.⁵ A value of 2000 for the coefficient or relative risk aversion effectively captures the case of an infinitely risk averse long-term investor. This investor seeks to minimize long-run risk regardless of expected

⁵Campbell and Viceira (1999) and Chacko and Viceira (2005) show that the optimal asset allocation is relatively insensitive to the choice of value for the elasticity of intertemporal substitution. We also set the subjective discount rate to 8% at an annual rate. The portfolio solutions are also not highly sensitive to this assumption.

portfolio return. For comparison, the rightmost column of the table reports the portfolio held by an infinitely risk averse investor with a short-term horizon. This is the portfolio with minimum short-term variance.

The unit relative risk aversion investor allocates 50% of his portfolio to each currency, regardless of his home currency area. This result is not driven by the data, but rather from imposing that the expected log return on the domestic and on the foreign currency are equal.⁶ We follow CVW in adopting this convention because it allows us to focus on the demand for currencies driven by real interest rate risk hedging considerations. As the investor becomes more risk averse, the optimal allocation starts diverging from the 50-50 allocation towards the currency that the investor perceives to be less risky at his investment horizon.

As risk aversion increases, long-term EMU investors place greater weight on the euro, to the extent that highly risk averse long-term EMU investors are either fully invested or overinvested in the euro regardless of which other currency they have available for investment. By contrast, long-term US investors, long-term British investors and long-term Japanese investors decrease the allocation to their own currencies as risk aversion increases, and accordingly increase their allocation to the euro. Highly risk averse long-term investors all allocate more than 50% of their wealth to the euro regardless of their home currency, with British investors allocating more than 75% of their wealth. Clearly, these investors consider the euro to be a safe currency that helps them hedge real interest risk at home. This is in sharp contrast with the optimal minimum-risk currency allocations for conservative short-term investors shown in the rightmost column of Table 1. This column shows that conservative short-term investors are always fully or almost fully invested in their home currency regardless of their home currency.

Figure 1 provides intuition about why short-term conservative investors prefer their home currency, but long-term conservative investors optimally allocate a highly significant fraction of their savings to the euro. Each panel in Figure 1 shows the annualized standard deviation of the real returns on the short-term bonds included in each of the currency pairs at different horizons, ranging from 1 to 100 quarters. The standard deviations are those implied by our estimated VAR models from the

⁶The unit relative risk aversion investor is fully invested in the instantaneous speculative portfolio, which maximizes the average log portfolio return. The result that this portfolio places equal weight on domestic and foreign currency when their expected log return are identical follows from the relation between log portfolio return and log returns on individual assets. See Campbell and Viceira (2002), equation (2.21).

perspective of a non-euro investor.

This figure shows that foreign investors see the euro as exhibiting considerably more volatility than their own domestic currency at short horizons. For example, the US dollar exhibits a 1-quarter standard deviation of about 1% per annum and the euro exhibits a standard deviation of 12% p.a. from the perspective of a short-term US investor. Of course, the larger variability of the euro reflects the short-term volatility of the US dollar-euro exchange rate. This helps explain why a short-horizon conservative US investor will choose to invest only in his home currency.

However, as the horizon increases the standard deviation of the euro declines rapidly, while the standard deviation of each of the other currencies increase. In the case of the British investor, the standard deviation of the euro even falls slightly below the standard deviation of the pound at long horizons. At long horizons, fluctuations in the real return on a euro investment appear to be as volatile or even less volatile than fluctuations in domestic real interest rates in each of the other currencies, even after accounting for real exchange rate long-run variability. Thus long-horizon conservative investors do not view the euro as being much riskier than their home currency. Instead, they view holding short-term bonds denominated in euros as not being riskier than holding short-term bonds denominated in their own home currency.

Both Table 1 and Figure 1 are based on estimates from a sample period that extends far back before the introduction of the euro. To isolate the effect of the introduction of the euro, Figure 2 reproduces Figure 1 using VAR estimates based on the sample period (1999.Q1-2005.Q4). The plots in this figure show that real interest rate volatility has declined in all currencies in the latter period. However, this reduction has been roughly proportional, making the euro still an attractive currency to hold by US, Japanese, and British long-term conservative investors.

Figure 3 helps calibrate the magnitude of the reduction in real interest volatility in the euro period. Similar to Figure 1 and Figure, each panel in Figure 3 plots the annualized standard deviation of the real return on German short-term bonds from the perspective of either a US investor, a British investor, or a Japanese investor. Each panel in the figure plots the standard deviation generated by a VAR estimated for the full sample period 1973-2005 (blue line), the pre-euro sample period 1973-1998 (green line), and the post-euro sample period 1999-2005 (red line). Figure 3 shows that the introduction of the euro has coincided with a period of significant decline in the long-term volatility of real interest rates and exchange rates in euro-denominated short-term bonds, relative to the period that preceded the introduction

of the common currency. This decline has been most significant from the perspective of British investors, although it is also important from the perspective of US investors.

If the euro has provided investors with a reserve currency in the sense that it provides a vehicle for investors to hedge real interest rate risk around the world, a natural question to ask is whether this has resulted in lower average real interest rates in the EMU. In equilibrium, one might expect that investors who have a desire to hold a currency will be willing to receive lower compensation from holding it. In recent work, Hassan (2008) explores this question, and finds that excess returns to US investors on EMU member bonds fell by 1.5 percentage points after the introduction of the euro. The magnitude of this reduction is both economically and statistically significant.

Hassan (2008) shows that, more generally, there appears to be a robust negative relation between interest rate differentials with respect to the US and the economic size of a currency area, as measured by its share of total O.E.C.D. output. In the period 1980-2007, bonds from a currency with a 10% share of total O.E.C.D. output returned to US investors between 2 and 3 percentage points less than bonds from a currency area with a very small share of total output.

Of course, an interesting question is why in equilibrium larger economic areas enjoy lower interest rates, and currency unions result in further reductions in interest rates for participating countries. Hassan (2008) argues that consumption risk insurance is the mechanism that explains this phenomenon. Larger economic areas represent a larger share of global consumption of both tradable goods and non-tradable goods. This means that adverse shocks to a large economic area are more likely to represent an adverse shock to global consumption, against which risk averse investors around the world want to protect themselves.

But the assets providing the hedge are precisely bonds from this area—as well as stocks representing ownership of production of the area non-tradable goods. The reason is that when the supply of non-tradable goods in a particular area experiences an adverse shock, its currency tends to appreciate, as non-tradable goods become relatively more expensive. This appreciation in turn results in positive returns for the bonds issued in the area, thus making these bonds attractive assets to hold for risk averse investors around the globe.

3 The Euro as a Reserve Currency for Aggressive Investors

Section 2 has shown empirical evidence suggesting that the euro provides global investors with a stable currency that helps them hedge real interest rate risk—or reinvestment risk. Equation (1) shows that this is the risk which concerns conservative long-term investors the most, as these investors avoid holding risky assets in their portfolios.

By contrast, equation (1) shows that aggressive and moderately risk averse investors—whose risk tolerance ($1/\gamma$) is non-zero—are willing to hold risky assets such as equities in their portfolios. For example, many investors, particularly institutional investors, hold internationally diversified equity portfolios. These investors face the important decision of deciding how much of the currency exposure implied by their portfolio holdings they want to hedge.

An unhedged position in international equity corresponds to a long position in foreign currency equal to the equity holding. Investors can alter this position, enhancing it or offsetting it, by taking simultaneous long or short positions in short-term bonds denominated in the foreign currency.⁷ A fully hedged position corresponds to a zero net position in foreign currency, which the investor achieves by effectively shorting bonds in the foreign currency one-for-one with the currency position implicit in the equity position, and using the proceeds to invest in bonds denominated in the investor's home currency. This results in pure exposure to stock market risk from the foreign currency area, with zero net exposure to the foreign currency. A fully hedged currency position is equivalent to a zero net demand for the currency.

An unhedged foreign equity position is one in which the investor does not take any positions in foreign and domestic bonds to offset the currency exposure implied by the equity position. This is equivalent to having a net demand for the foreign currency equal to the amount invested in the foreign stock. Of course, zero or full hedging are not the only possible choices for investors. They may choose exposures, or net foreign currency demands, along a continuum of values that include overhedging—effectively holding a short net exposure to the currency—and underhedging.

⁷This can be done cheaply and efficiently through appropriate positions in forward currency contracts.

CSV study optimal currency demand—or equivalently, optimal currency hedging—from the perspective of an investor who is already invested in a portfolio of international assets, and chooses the vector of currency exposures that minimizes the short-term volatility of his overall portfolio. They label the resulting vector of optimal risk-minimizing net currency demands as “risk management net currency demands.”

Formally, CSV estimate the second term $\Sigma^{-1}\sigma_1$ in equation (1) when the benchmark asset 1 is an internationally diversified portfolio of equities or bonds, and the choice variable is a vector of net currency demands. In that case, $\Sigma^{-1}\sigma_1$ takes the form

$$-\text{Var}_t(\mathbf{f}_{t+1})^{-1}\text{Cov}_t(x_{p,t+1}^h, \mathbf{f}_{t+1}) \quad (3)$$

where $x_{p,t+1}^h$ denotes the currency hedged log return on the portfolio of international risky assets in excess of the investor’s domestic short-term nominal interest rate, and \mathbf{f}_{t+1} denotes the vector of log excess currency returns.⁸

Equation (3) shows that the vector of risk management net currency demands is proportional to the negative of the covariance between the returns on the assets held in the portfolio (say, stocks) and exchange rates.

Risk management currency demands are positive when stock returns and exchange rates are negatively correlated. To understand why risk management currency demands are proportional to the negative of the correlation between stock returns and exchange rates, note that a negative correlation implies that the domestic currency tends to depreciate with respect to the foreign currency when stocks fall. Equivalently, the returns from holding foreign currency tend to be positive when the returns from holding stocks fall. Thus equity investors can reduce portfolio volatility by holding positive net foreign currency positions or, equivalently, by underhedging the currency exposure implied by their foreign equity positions.

If stock returns and exchange rates are uncorrelated, risk management currency demand is zero. In this case, holding currency exposure adds volatility to investors portfolios and, unless this volatility is compensated, investors are better off holding no currency exposure at all or, equivalently, by engaging in full currency hedging.

⁸Note that the log excess return on currency c is equal to

$$f_{c,t+1} = \Delta s_{c,t+1} + i_{c,t} - i_t^d,$$

where $\Delta s_{c,t+1}$ is the change in the log exchange rate, $i_{c,t}$ is the log short-term nominal interest rate in currency c , and i_t^d is the domestic counterpart of the latter.

If stock returns and exchange rates are positively correlated, investors can reduce portfolio volatility by overhedging, that is, by shorting foreign currency in excess of what would be required to fully hedge the currency exposure implicit in the stock portfolio.

CSV estimate risk management net currency demands for investors holding both an equally-weighted portfolio and a value-weighted portfolio of global stocks comprising the EMU area (or “Euroland”), plus Australia, Canada, Japan, Switzerland, the UK, and the US. They also consider investors who are fully invested in each of these markets individually. Their estimates consider the 30-year period between July 1975 and December 2005, as well as the subsamples running from 1975 through 1989 (“Subsample I”), and from 1990 through 2005 (“Subsample II”). They define Euroland as a value-weighted stock basket that includes Germany, France, Italy, and the Netherlands; these are the EMU countries with the longest history of stock returns, interest rates, and exchange rates available. Prior to the introduction of the euro, they consider a basket of national currencies. Their results are robust to restricting the study to include only the German stock market and the deustchemark prior to the introduction of the euro.

Table 2, which reproduces Table IV in their paper, reports the vector of estimated optimal risk management currency demands generated by the equally-weighted global stock portfolio, for both the full sample and the two subsamples. Panel A considers the case in which investors have access to all seven currencies from the countries included in the portfolio. Panel B excludes Canada and Switzerland from the analysis, as the currency and stock market of each are highly correlated with those in the US and Euroland markets, respectively.⁹

The estimated optimal currency exposures reported in the table reflect the amounts optimally invested in each currency per euro of exposure to the global equity portfolio. By construction, these exposures add up to zero; that is, the optimal currency portfolio is a zero net investment portfolio. These exposures can be easily restated in terms of hedging demands by noting that zero net currency demand is equivalent to fully hedging the currency position implied by the stock portfolio, which is invested about 14% in the equities of each currency area.

⁹CSV show that the vector of optimal currency demands generated by a given global portfolio is the same regardless of the currency base when investors from each currency have access to all other currencies. Accordingly, the table reports only one set of currency demands, which add up to zero.

Panel A shows that the risk management currency portfolio includes statistically and economically significant exposures to the euro and the Swiss franc in the full sample, at 32% and 27% respectively. These are the largest long optimal risk management net currency demands after the optimal 40% exposure to the US dollar. The 32% exposure to the euro means that, say, a British investor holding the equally weighted global equity portfolio would optimally choose not to hedge his 14% exposure to Euroland stock markets by shorting short-term Euroland government bonds (say, German or French) worth 14 pounds per 100 pounds invested in the equity portfolio; instead, he would buy euro bonds worth 18 pounds, for a total euro exposure of 32 pounds per 100-pound equity investment. Additionally, the investor would also hold long exposures of 27 pounds and 40 pounds to the Swiss franc and the US dollar respectively. He would then finance the long euro, Swiss franc, and US dollar positions with the proceeds from short positions worth 11, 61, 17, and 11 pounds in the Australian dollar, the Canadian dollar, the Japanese yen and the British pound itself. Equivalently, the optimal risk management currency portfolio implies underhedging the euro, Swiss franc, and US dollar exposures implied by the equally-weighted global equity portfolio, and overhedging the exposures to all other four currencies.

The optimal risk management net currency demand for the euro increases dramatically when we exclude the Swiss franc from the menu of currencies. Panel B shows that in that case the net demand for euro increases to 56% and becomes statistically significant at the 1% significance level, suggesting that the euro and the Swiss franc are very close substitutes. Strikingly, Panel B also shows that the demand for the euro becomes even stronger in the second subperiod, when at 79% is at least twice as large as the demand estimated for the first subperiod. Figure 4, which reproduces Figure 2 in CSV, provides visual intuition of what drives this result. This figure plots the 3-month annualized return of the euro against an equally weighted basket of other currencies, together with the currency-hedged excess global equity return. It shows a markedly increase in the negative comovement of the euro with the global equity portfolio in the second subsample.

Panel B in Table 2 also shows that the exclusion of the Canadian dollar from the menu of currencies results in a very small and statistically insignificant demand for the US dollar. Thus the optimal exposures to the US dollar and the Canadian dollar are not independent of each other: It is a long-short US dollar-Canadian dollar what helps global equity investors reduce portfolio risk. The subsample analysis in Table 2 also suggests a diminishing role of the dollar in the second subperiod as a currency that helps investors hedge adverse movements in global equity markets.

The empirical analysis of risk management currency demands of CSV suggests that the euro, together with the Swiss franc, and the US dollar, has become a reserve currency for global equity investors. By holding exposure to the euro, these investors can reduce the volatility of their internationally diversified equity portfolios, because the euro, like its close substitute the Swiss franc, and the US dollar, tend to strengthen when global stock markets fall. CSV show that the reductions in portfolio volatility that investors can achieve by following optimal risk management currency exposure policies are important, both in economic and statistical terms, relative to conventional policies of either no hedging or fully hedging currency exposures. These gains are particularly substantial for investors whose domestic currencies are not reserve currencies. Currency movements during the financial crisis of 2008, when reserve currencies have tended to strengthen against other currencies, have confirmed the attractiveness of holding reserve currencies as hedges for equity investors.

4 The Euro and Capital Market Integration in the EMU

Sections 2 and 3 have discussed empirical evidence suggesting that the adoption of the euro has resulted in a reserve currency that benefits investors around the world. This section explores whether the creation of the common currency has also resulted in additional benefits for EMU investors, by promoting better risk sharing. Specifically, we look for empirical evidence of an increasing importance of a euro-wide discount factor pricing the national stock markets in the EMU area in the period subsequent to the creation of the euro. If national stock markets are priced at the EMU level, this would suggest improved integration of the national stock markets in the euro zone.

Our empirical analysis starts from the asset return decomposition of Campbell and Shiller (1988) and Campbell (1991). This decomposition writes unexpected stock returns as a linear combination of revisions in expected future dividends (cash flow news) and returns (discount rate news):

$$\begin{aligned}
 r_{t+1} - E_t r_{t+1} &\approx (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j \Delta d_{t+1+j} - (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j r_{t+1+j} \\
 &\equiv N_{CF,t+1} - N_{DR,t+1},
 \end{aligned} \tag{4}$$

where r_t denotes log (or continuously compounded) stock returns, d_t denotes net payouts (or cash flows) on the stock, Δ denotes the first-difference operator, and ρ is a loglinearization constant equal to $1/(1 + \exp(\overline{d-p}))$, where $\overline{d-p}$ is the average log dividend-price ratio. The stock return decomposition shown in equation (4) says that stock returns respond positively to changes in investors' expectations of future cash flows, and negatively to changes in required discount rates.

In an integrated capital market, there is no reason to expect that cash flow news will be highly correlated across stocks. Cash flow news reflects changes in dividend policies and earnings, which in turn reflect the economic realities of individual firms and sectors.

However, required returns are set by investors, not firms. An integrated capital market is by definition one in which securities are priced by a common discount factor. In the context of our empirical exercise, one should expect that as national stock markets become more integrated, the returns of national stock markets will exhibit increasing covariation, or beta, with EMU-wide discount rate news.

To test this hypothesis we adapt the CAPM beta decomposition of Campbell and Vuolteenaho (2004) and Campbell, Polk, and Vuolteenaho (2010) to test for capital market integration. The conditional CAPM beta of any asset with respect to the market is given by

$$\beta_{i,M} = \frac{\text{Cov}_t(r_{i,t+1}, r_{M,t+1})}{\text{Var}_t(r_{M,t+1})}. \quad (5)$$

Simple substitution of the asset return decomposition (4) for the case $r = r_M$ in the numerator of (5) allows us to write the CAPM beta of any asset as

$$\beta_{i,M} = \beta_{i,CFM} + \beta_{i,DRM},$$

where

$$\beta_{i,CFM} \equiv \frac{\text{Cov}_t(r_{i,t+1}, N_{M,CF,t+1})}{\text{Var}_t(r_{M,t+1})} \quad (6)$$

and

$$\beta_{i,DRM} \equiv \frac{\text{Cov}_t(r_{i,t+1}, -N_{M,DR,t+1})}{\text{Var}_t(r_{M,t+1})}. \quad (7)$$

If stock markets have become more integrated with the adoption of the euro, we should expect the discount rate news CAPM beta of national stock markets $\beta_{i,DRM}$ to be larger after the adoption of the euro.

Following this intuition, we estimate sample counterparts of the total CAPM beta (5), the cash flow beta (6) and the discount rate beta (7) for the pre-euro and post-euro periods, and test whether those betas have changed significantly between both periods. We expect discount rate betas (7) to have increased in the post-euro period. Of course, the integration process might have been dynamic, occurring not at a single date but rather during the years surrounding the adoption of the euro. In that case, our tests will be biased against finding evidence of increased market integration.

Our estimates of betas are based on time series of monthly unexpected stock returns, cash flow news and discount rates for each national stock market and for a value-weighted basket of stock markets in the EMU area. Of course, the components of stock returns are not directly observable, and must be estimated. Following Campbell (1991) and Campbell and Mei (1993), we estimate a first-order vector autoregressive (VAR) system for each market, and use the estimates to obtain estimates of unexpected stock returns, cash-flow news, and discount rate news.

The VAR system for each market includes the log return on the market in excess of the local short-term interest rate, the log dividend-price ratio on the local market, the local nominal short-term log interest rate, and the log real return on local short-term government bonds—i.e., the ex-post local real interest rate. We estimate a VAR system for each of the countries that joined the EMU, for the EMU-wide stock market,¹⁰ and for several non-euro developed markets—specifically, Japan, Norway, Sweden, Switzerland, the United Kingdom, and the United States. The source for stock market returns and dividend price ratios is Morgan Stanley Capital International (MSCI). The source for exchange rates, short-term interest rates, and inflation is the International Financial Statistics database published by the International Monetary Fund. Our sample period extends from July 1975 through November 2008.

Table 3 reports the full sample, the pre-euro, and the post-euro estimates of the total CAPM beta (5) of each market with respect to the EMU-wide stock market. The last column in the table also reports the results from testing whether the pre- and post-euro betas are statistically significant. The table shows an increase in the average beta for euro-zone markets. However, this change is not uniform and it is not statistically significant in most cases. Some markets like Austria or Belgium have experienced large, statistically significant increases, but most other markets have experienced

¹⁰The VAR system for the EMU-wide stock market uses German nominal interest rates and inflation as proxies for the EMU area nominal interest rates and inflation. The EMU-wide stock market returns are measured in deutschemarks in the pre-euro period.

only small increases or no increases at all—with one market, Ireland, experimenting a decrease. The average beta for non-euro markets is only slightly larger in the post-euro period, although this average hides large cross-sectional variation in both directions.

The results shown in Table 3 might lead to conclude that there is little evidence that the adoption of the euro is correlated with an increase in stock market integration across EMU economies. However, we have noted that total beta reflects the covariation of stock returns with both aggregate cash-flow news and discount rate news. It could well be the case that stock market integration has occurred simultaneously with offsetting changes in the covariation of stock returns with aggregate cash flow news, perhaps because of increased sector specialization of EMU economies. Accordingly, one might want to isolate the discount rate news component of the aggregate EMU stock market, and test whether national stock markets in the euro area have changed their covariance with respect to aggregate discount rate news.

Table 4 shows the discount rate beta (7) of national stock markets with respect to discount-rate news in the EMU-wide stock market. The results shown in this table are remarkably different from those shown in Table 3. Table 4 shows that, except for the Greek stock market, all post-euro betas in the euro zone are larger than the pre-euro betas. This differences are economically large in most cases, and statistically significant at the 1% level in five of the euro zone markets—and statistically significant at the 10% level or lower in seven of the euro zone markets. The average discount rate beta has increased from about 0.54 to 0.82.

The betas of non-euro zone markets also show statistically significant changes. However, these changes go in all directions. The Swedish stock market has experimented an economically and statistically significant increase in its discount rate beta with respect to the EMU stock market, while other markets like the Norwegian stock market and the U.K. stock market have seen their discount rate betas decrease substantially. The Swiss market has seen an economically small but statistically significant increase in its discount rate beta. One possible interpretation of these results is that some non-euro markets like the Swedish market have effectively become priced at the euro level even though they are not part of the euro, perhaps through increased economic integration with the euro area, while others have experimented a decline in the importance of euro factors in their pricing.

Table 5 furthers this analysis by looking at the covariation of innovations to the log dividend-price ratio of each national market with the innovations to the log dividend-

price ratio of the aggregate EMU-wide stock basket. This table uses the innovations to the log dividend-price ratio as a direct measure of discount-rate news. Campbell, Lo, and Mackinlay (1997) note that simple manipulation of the log linear decomposition of log returns (4) implies that

$$d_t - p_t = -\frac{k}{1 - \rho} - \text{E}_t \left[\sum_{j=0}^{\infty} \rho^j \Delta d_{t+1+j} \right] + \text{E}_t \left[\sum_{j=0}^{\infty} \rho^j r_{t+1+j} \right],$$

where $k \equiv -\log(\rho) - (1 - \rho) \log(1/\rho - 1)$. If expected dividend growth is constant or approximately constant (Cochrane 2007), the dividend-price ratio should be a direct measure of expected future discount rates and its innovations a direct measure of discount-rate news. In fact, the dividend-price ratio has been shown to be the most successful forecasting variable for stock returns (Campbell and Shiller 1988, Fama and French 1988, Campbell and Thompson 2008, Cochrane 2007). In fact, it is the main predictor of stock returns in our estimated VAR systems.

Table 5 reports the regression coefficient that obtains from regressing shocks to the log dividend-price ratio of each national stock market onto shocks to the log dividend-price ratio of the EMU-wide stock basket. This table provides strong evidence of an economically large increase in the covariation of national discount rate news in the euro area with EMU-wide discount rate news. By contrast, there is not much evidence of an increase in the covariation of discount rate news in non-euro stock markets with EMU-wide discount rate news, with the exception of Sweden. These findings suggest that the results shown in Table 4 are driven by increased covariation of discount rate news in the euro area which has not happened outside the area. As such, they are consistent with an interpretation that there has been increased integration of the national stock markets in the euro area after the adoption of the euro.

5 Concluding Remarks

This article has examined whether the adoption of the euro has brought benefits to investors around the world. We have provided new empirical evidence and summarized recent empirical findings suggesting that the euro has become a reserve currency for global investors, both conservative and risk tolerant. Our extension of the work of Campbell, Viceira and White (2003) suggests that, in the absence of domestic inflation-indexed bonds, the euro can help conservative long-term investors to hedge

real interest rate risk. While the optimal portfolios of short-term conservative investors remain heavily biased toward domestic short-term government bonds, the optimal portfolios of long-term conservative investors allocate a significant fraction of holdings to euro-denominated short-term government bonds. Long-term conservative investors optimally invest in euros because their currency returns appear to be negatively correlated with revisions in expected future real interest rates. Essentially, real interest rates appear to be more stable in the euro area. At short-horizons, short-term exchange rate volatility makes currency returns on the euro highly volatile relative to returns on domestic short-term government bonds. However, this volatility appears to subside significantly at long horizons, making euro-denominated short-term government bonds attractive assets to long-term conservative investors worldwide.

We have also summarized the recent findings in Campbell, Serfaty-de Medeiros, and Viceira (2010) about the benefits of holding euros for global equity investors. They show robust empirical evidence that excess currency returns on the euro exhibit a negative correlation with global stock market returns. Global equity investors can achieve statistical and economically significant reductions in the volatility of their portfolios by not hedging their exposure to the euro.

We have also provided new empirical evidence about increased market integration of national stock markets in the EMU. Consistent with the intuition that an integrated capital market is one in which there is a common discount factor pricing securities, we have explored if stocks in the euro area have moved from a regime in which national stock markets were priced with discount rates that were predominantly country-specific, to a regime in which national stock markets are predominantly priced by an euro-wide common discount rate. Our empirical examination of this question builds on the CAPM beta decomposition of Campbell and Vuolteenaho (2004) and Campbell, Polk, and Vuolteenaho (2010). We have provided evidence of increased covariation of unexpected returns and revisions in expectations of discount rates of national stock markets in the euro area with revisions in expectations of EMU-wide discount rates. This evidence suggests improved capital market integration in the euro zone, and consequently improved risk sharing among EMU economies.

Therefore, the evidence suggests that the adoption of the euro has benefited investors around the world, by providing them with a reserve currency. Investors in the countries that joined the euro have also benefited from increased capital market integration of their national stock markets, thus improving risk sharing in the euro zone.

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Table 1
Optimal Currency Allocation

	Currency	Relative Risk Aversion			Min ST
		1	5	2000	Variance
Domestic: US	Dollar	50.0	41.2	35.1	98.8
	Euro	50.0	58.8	64.9	1.2
Domestic: Euro	Euro	50.0	88.5	111.3	100.6
	Dollar	50.0	11.5	-11.3	-0.6
Domestic: UK	Pound	50.0	30.0	23.4	97.3
	Euro	50.0	70.0	76.6	2.7
Domestic: Euro	Euro	50.0	95.8	110.9	100.2
	Pound	50.0	4.2	-10.9	-0.2
Domestic: Japan	Yen	50.0	49.9	47.5	98.2
	Euro	50.0	50.1	52.5	1.8
Domestic: Euro	Euro	50.0	88.3	111.2	101.3
	Yen	50.0	11.7	-11.2	-1.3

This table reports optimal portfolio allocations to short-term bonds in each currency pair for Epstein-Zin investors. The allocations are based on VAR estimates for the period 1973.Q1-2005.Q4. The VAR includes the real interest rate for each currency included in the pair, and the real exchange rate between the two currencies. The allocations impose equality of the expected log return on the currencies in the pair.

Table 2
Optimal Currency Exposure for an Equally Weighted Global Equity Portfolio:
Multiple Currency Case

Time Period	Currency						
	Euroland	Australia	Canada	Japan	Switzerland	U.K.	U.S.
Panel A : 7 country optimization							
Full period	0.32*	-0.11	-0.61***	-0.17*	0.27*	-0.10	0.40**
	(0.17)	(0.09)	(0.16)	(0.09)	(0.15)	(0.11)	(0.18)
Subperiod I	0.14	-0.05	-0.63**	-0.20	0.22	-0.09	0.62*
	(0.21)	(0.12)	(0.26)	(0.14)	(0.18)	(0.15)	(0.35)
Subperiod II	0.44	-0.17	-0.65***	-0.08	0.37	-0.12	0.22
	(0.28)	(0.14)	(0.21)	(0.10)	(0.23)	(0.14)	(0.19)
Panel B : 5 country optimization							
Full period	0.56***	-0.27***		-0.14*		-0.09	-0.06
	(0.11)	(0.10)		(0.08)		(0.11)	(0.14)
Subperiod I	0.35**	-0.15		-0.15		-0.10	0.05
	(0.17)	(0.11)		(0.11)		(0.15)	(0.20)
Subperiod II	0.79***	-0.47***		-0.06		-0.11	-0.15
	(0.13)	(0.12)		(0.11)		(0.13)	(0.17)

Source: Campbell, Serfaty-de Medeiros, and Viceira (2010). This table considers an investor holding a portfolio composed of stocks from all countries, with equal weights, who chooses a vector of positions in all available foreign currencies to minimize the variance of his portfolio. In this case, the optimal currency positions do not depend on the investor's base country. Panel A considers a case where all seven currencies are available, whereas Panel B excludes the Canadian dollar and the Swiss franc. Within each panel, rows indicate the time period over which the optimization is computed, columns the currencies used to manage risk. The full period runs from 1975 to 2005, the first subperiod covers the years 1975 through 1989, and the second subperiod covers the rest of the sample. Reported currency positions are the amount of dollars invested in foreign currency per dollar in the portfolio. We run monthly regressions on overlapping three-month returns. Standard errors are corrected for autocorrelation due to overlapping intervals using the Newey-West procedure.

Table 3
CAPM Beta with Respect to EMU Basket
(1975.07 - 2008.11)

	<u>Full Sample</u>	<u>Pre €</u>	<u>Post €</u>	<u>Difference</u>
Euro Zone				
Austria	0.861	0.772	1.036	**
Belgium	0.956	0.827	1.200	***
Finland	1.089	0.869	1.189	
France	1.074	1.072	1.085	
Germany	0.993	1.005	1.017	***
Greece	0.730	0.542	0.945	
Ireland	0.765	0.870	0.621	
Italy	0.901	0.863	0.982	
Luxembourg	N/A	N/A	N/A	
Netherlands	0.843	0.860	0.826	***
Portugal	0.721	0.629	0.711	
Spain	0.916	0.859	1.018	
Mean Euro Zone	0.895	0.833	0.967	
Japan	0.387	0.472	0.582	
Norway	0.949	1.005	0.873	
Sweden	1.028	0.833	1.405	***
Switzerland	0.836	0.913	0.688	***
United Kingdom	0.993	1.090	0.835	***
United States	0.578	0.508	0.720	***
Mean No euro	0.795	0.804	0.851	

The Difference column provides significance levels of the test of the null hypothesis that the pre-euro and post-euro betas are equal. A single asterisk indicates rejection of the null of equality at the 10% significance level; two asterisks indicate rejection at the 5% significance level; and three asterisks indicate rejection at the 1% significance level.

Table 4
Beta Of Returns On National Stock Markets
With Respect to EMU Discount Rate News
(1975.07 - 2008.11)

	<u>Full Sample</u>	<u>Pre €</u>	<u>Post €</u>	<u>Difference</u>
Euro Zone				
Austria	0.523	0.386	0.786	***
Belgium	0.587	0.357	1.022	***
Finland	0.772	0.510	0.924	
France	0.798	0.705	0.985	***
Germany	0.596	0.516	0.811	***
Greece	0.866	0.594	1.021	
Ireland	0.535	0.607	0.437	
Italy	0.717	0.675	0.808	**
Luxembourg	N/A	N/A	N/A	
Netherlands	0.543	0.492	0.656	***
Portugal	0.700	0.576	0.728	*
Spain	0.630	0.507	0.862	
Mean Euro Zone	0.661	0.539	0.822	
Japan	0.451	0.405	0.546	**
Norway	0.818	0.959	0.570	***
Sweden	0.743	0.528	1.160	***
Switzerland	0.520	0.493	0.569	***
United Kingdom	0.757	0.799	0.699	**
United States	0.593	0.530	0.724	*
Mean No euro	0.647	0.619	0.711	

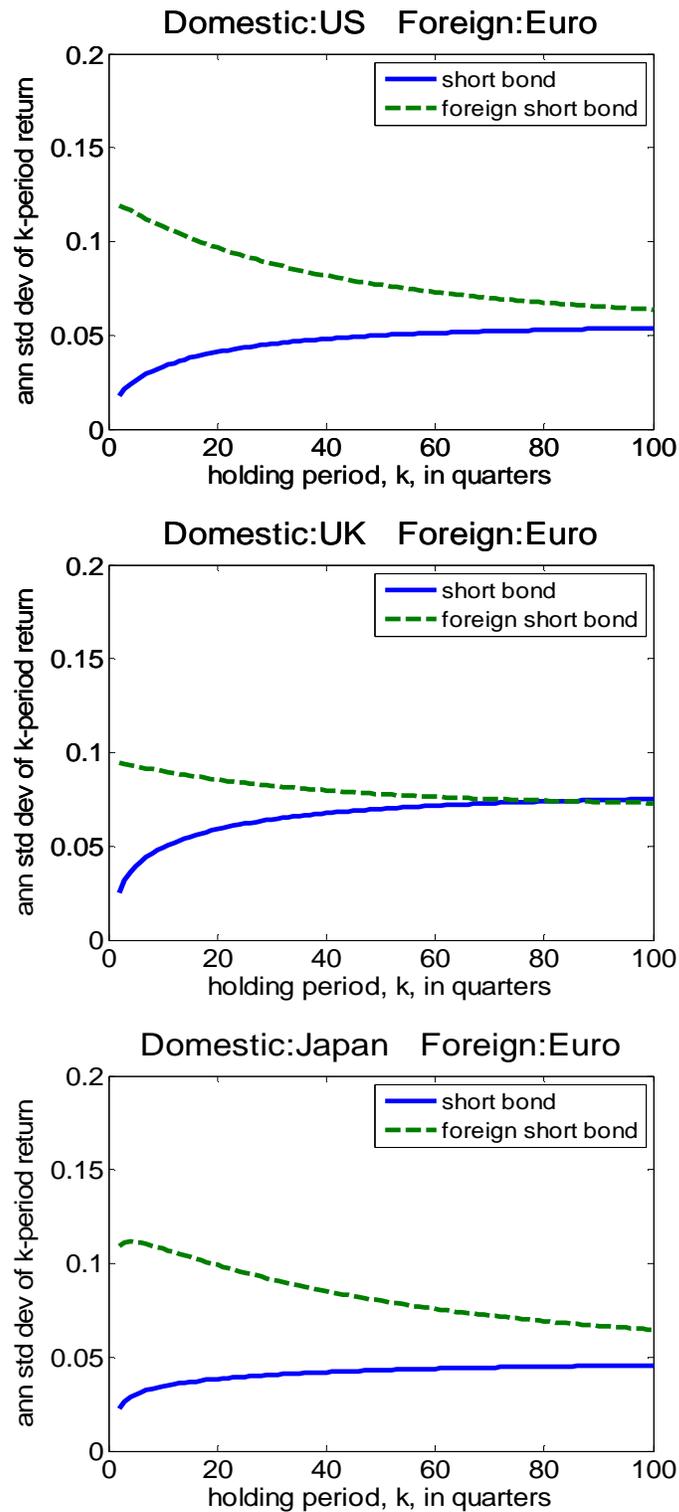
The Difference column provides significance levels of the test of the null hypothesis that the pre-euro and post-euro betas are equal. A single asterisk indicates rejection of the null of equality at the 10% significance level; two asterisks indicate rejection at the 5% significance level; and three asterisks indicate rejection at the 1% significance level.

Table 5
Beta Of Discount Rate News On National Markets
With Respect to EMU-Wide Discount Rate News
(Proxied by D/P Ratio, 1975.07 - 2008.11)

	Full Sample	Pre €	Post €	Difference
Euro Zone				
Austria	0.356	0.197	0.853	***
Belgium	1.471	1.257	2.156	***
Finland	0.913	0.734	1.119	**
France	1.002	0.932	1.243	**
Germany	0.846	0.767	1.299	***
Greece	0.248	-0.126	0.618	
Ireland	0.334	0.010	0.739	***
Italy	0.747	0.541	1.392	***
Luxembourg	N/A	N/A	N/A	
Netherlands	1.177	1.142	1.342	
Portugal	0.274	0.065	0.442	
Spain	0.827	0.748	1.060	
Mean Euro Zone	0.745	0.570	1.115	
Japan	0.152	0.166	0.103	
Norway	0.724	0.665	0.986	*
Sweden	0.756	0.609	1.237	***
Switzerland	0.389	0.416	0.308	
United Kingdom	1.172	1.255	0.939	***
United States	0.525	0.558	0.438	
Mean No euro	0.620	0.612	0.669	

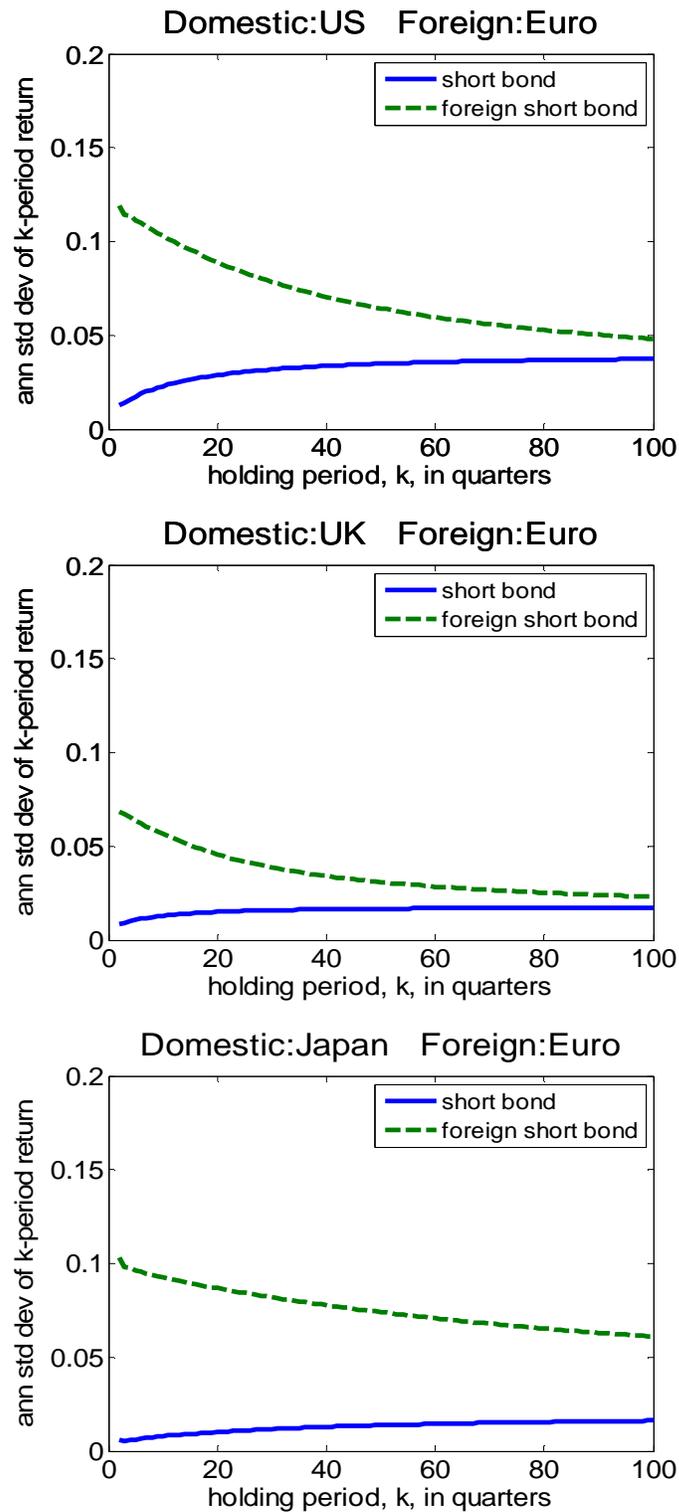
The Difference column provides significance levels of the test of the null hypothesis that the pre-euro and post-euro betas are equal. A single asterisk indicates rejection of the null of equality at the 10% significance level; two asterisks indicate rejection at the 5% significance level; and three asterisks indicate rejection at the 1% significance level.

**Figure 1. Real Interest Rate Risk
Across Investment Horizons (1973.Q1-2005.Q4)**



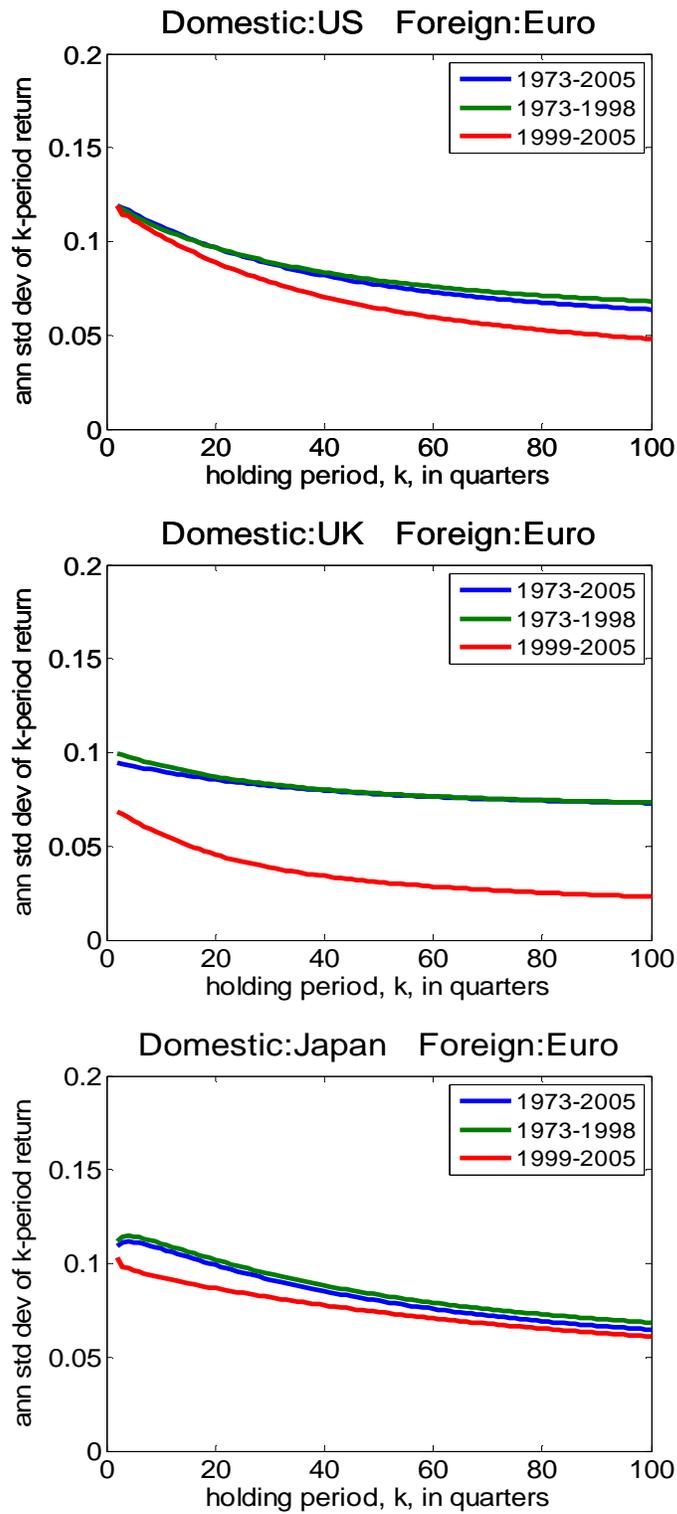
Each panel in this figure reports annualized standard deviation of returns on domestic and euro-denominated short-term bonds at different horizons. Estimates implied by VAR (1) of domestic ex-post real interest rate, euro ex-post real interest rate, and real exchange rate with respect to the euro for the period 1973.Q1-2005.Q4.

**Figure 2. Real Interest Rate Risk
Across Investment Horizons (1999.Q1-2005.Q4)**



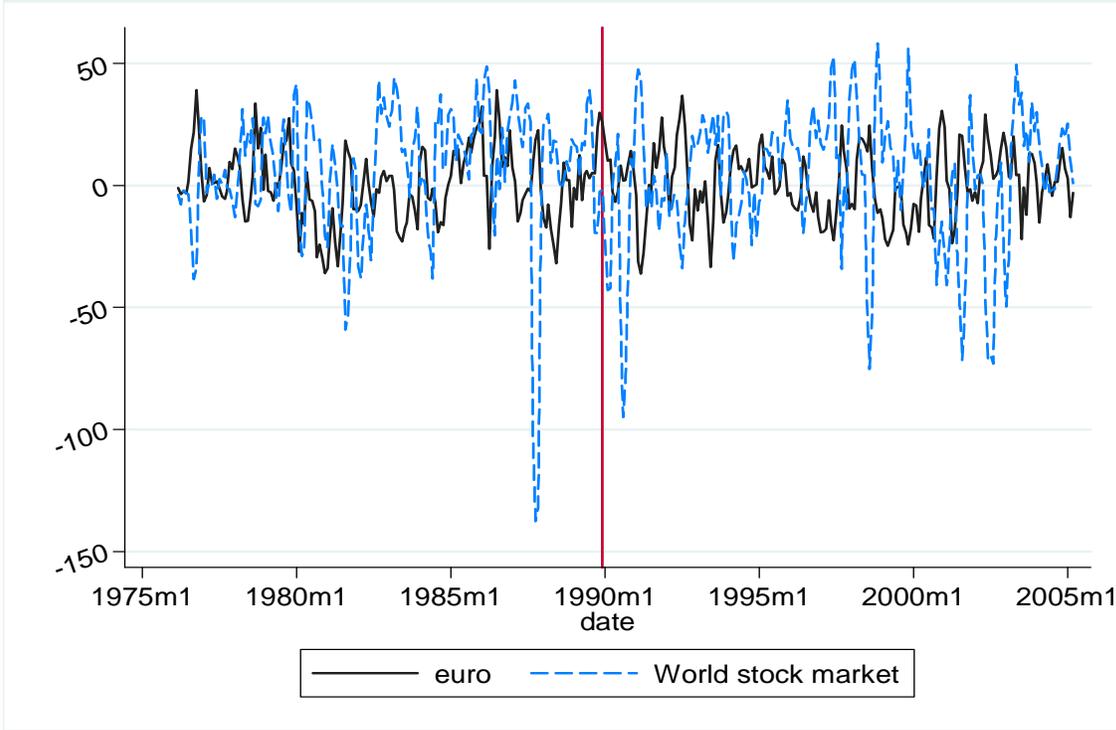
Each panel in this figure reports annualized standard deviation of returns on domestic and euro-denominated short-term bonds at different horizons. Estimates implied by VAR (1) of domestic ex-post real interest rate, euro ex-post real interest rate, and real exchange rate with respect to the euro for the period 1999.Q1-2005.Q4.

**Figure 3. Real Interest Rate Risk
Across Investment Horizons**



Each panel in this figure reports annualized standard deviation of returns on euro-denominated short-term bonds at different horizons. Estimates implied by VAR (1) of domestic ex-post real interest rate, euro ex-post real interest rate, and real exchange rate with respect to the euro for three different periods.

Figure 4. Excess Returns on the Euro and the Hedged World Stock Market Portfolio



Source: Campbell, Serfaty-de-Medeiros, and Viceira (2010).